THE SOIL SCIENCE SOCIETY OF FLORIDA

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1945 *

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ACKNOWLEDGMENTS

The Executive Committee of the Society wishes to take this opportunity to thank Hon. Millard F. Caldwell, Governor-elect of the State of Florida, for the time he took from his exceedingly active schedule to attend the Water Conservation Section of these meetings and for the very important part he took in them; also to thank Col. A. B. Jones, District Engineer, Corps of Engineers, Jacksonville, for the excellent paper prepared in the same field which, in his absence, was so ably presented by Mr. Harold A. Scott; also to thank Dr. Oskar Baudisch, Research Director, Saratoga Springs Commission, Saratoga Springs, N. Y., for coming so far and taking such a fine and active part in the discussions pertaining to the place of trace elements in the nutrition of plants and animals and, finally, too, our best thanks to Dr. Herman Gunter, Mr. Frank Holland, Editor Warren Roberts and a great many other leaders in research and extension work throughout the State for the truly indispensible part they took in the varied program covering as it does, many angles of water conservation and management, the development of a soil survey program for the State, and the important relationship existing between the so-called trace elements and the proper nutrition of both plants and animals as well as man.

It is also a pleasant duty to extend our very best thanks to the Committee on Arrangements consisting of Mr. A. C. Slaughter, Secretary Orlando Chamber of Commerce, Chairman, and Messrs. C. S. Rodebough and K. C. Moore; also to the Manager of the Orange Court Hotel and his staff for the excellent facilities which they placed at the disposal of the Society for the conduct of the meetings and for the prompt and courteous manner in which these facilities were extended; also to Miss Margery Hill of Orlando for the complete and accurate record she prepared of any and all oral discussions which followed the prepared presentations throughout the period of the meetings.

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DR. HERMAN GUNTER

DR. HERMAN GUNTER

Herman Gunter was born in Brooklyn, New York, on July 2, 1885. After completing his high school education he entered the University of Florida and received the degree Bachelor of Science in 1907, thus becoming one of the early graduates of the institution after its consolidation in Gainesville.

He was immediately appointed Assistant in the office of the Florida Geological Survey, served that office with distinction until 1919, at which time he was appointed State Geologist. He has served the State in that capacity for the past twenty-five years.

He is a member of numerous professional organizations, including The American Society of Geologists, The American Association for the Advancement of Science, The American Geophysical Union, The American Association of Petroleum Geologists, The American Water Works Association, The Florida Engineering Society, The Florida Academy of Sciences, and others. He served as Chairman of the Florida Section, American Water Sciences of the Florida Academy of Science in 1934. He is an honorary member of the University of Florida Chapter of Phi Beta Kappa, national honorary fraternity.

His only son, Herman, Jr., received his degree from the College of Arts and Sciences of the University of Florida in May, 1939.

Mr. Gunter's contributions to the development of the natural resources of the State have been numerous and fundamental. He has worked unceasingly for the conservation and proper use of underground water supplies. He has made valuable studies of her deposits of clay, dolomite, monazite and the various types of phosphate. These and other studies are being continued and the Bulletins issued by the Survey present authoritative information with respect to the geology and natural resources of the State and, as such, are in constant demand by potential industries seeking locations in the State.

His record of thirty-seven years of outstanding public service to the State, his distinguished contributions to her economic geology and the study of her natural resources, and the scientific and conservative approach which has characterized all of his work were deemed worthy of special recognition by his Alma Mater when, in the spring of the present year he was awarded the honorary degree of Doctor of Science by the University of Florida.

In view of the splendid contributions Dr. Gunter has made thru the years to the development of Florida's agriculture thru his early and comprehensive work on the location and management of her water resources, the systematic appraisal and development of her mineral resources, including her phosphates, his capable direction of the Soil Survey work in the State since the time of its inception and the splendid part he has taken in many of the meetings of our Society of which he is a Charter Member, it is indeed a pleasure and an honor to dedicate this, the Sixth Volume of the Proceedings, to him in recognition of the fine public service he has rendered.

DR. OSKAR BAUDISCH

DR. OSKAR BAUDISCH

Dr. Baudisch was born in 1881 in Bohemia, the heart of Europe, at a time when this strife-torn continent was enjoying one of its longest periods of peace and prosperity. Following his early education in his homeland he went to the University of Zürich for his doctors degree in 1905. This was followed by a period in the military service and this in turn by a period of research under Eugen Bamberger, predecessor of Richard Wilstätter, at the Federal Eidgenössische Technische Hochschule in Zürich. Here the main study was first of the chemical structure of the diazo oxides and subsequently the nitroso hydroxylamin compounds.

In 1907 Baudisch went to Manchester to work on terpene compounds at the Chemical Institute of Victoria University of which Sir W. H. Perkin,

inventor of the first organic dye, was director while Rutherford was director of the Physics Department. Following the work with dyes in Manchester he went to the dye industry near Frankfurt where he became interested in light chemistry and thence, on account of climate and health, back to the University of Zürich to work under Prof. A. Werner, Director of the Chemistry Department and where, in 1911, he received high honors for his work on Nitrite and Nitrate Assimilation and on a new Hypothesis of the Formation of the Precursors of Proteins in Plants. A year later he entered the Medical School as supplemental to his regular duties and studied medicine until the outbreak of the war. In the spring of 1912 he worked on light under most favorable circumstances in Italy and in the spring of 1914 received an appointment as Founder and Conductor of the Light Research Institute at Hamburg. However, the First World War suddenly put a stop to this project. The years that immediately followed were spent on critical work in plague control throughout Europe.

In 1919 a year was spent as Director of the Institute of Experimental Therapy at Neuberg and in the same capacity at the Institute of Physical Chemistry at Habers while awaiting the building of a new Kaiser Wilhelm Institute for Light Chemistry at Dahlem of which he was to be Director. This was never built due to post war financial conditions in Germany. Consequently an English position was accepted in Norway in 1920 but in 1921 an invitation from Yale University overruled all others for the opportunity it offered to come to America.

After two years of organic research and teaching photochemistry at Yale, several years were spent at the Rockefeller Institute of Medical Research where much time was given to light studies and magneto-chemistry, a new field of chemistry that has become so important in biology and in the early development of which Baudisch played such an important role. This led to the study of mineral waters in Mexico, in England and in Sweden in 1928 and ultimately at the Saratoga Springs, New York, and Warm Springs, Georgia. Indeed it was the warm personal interest of Governor F. D. Roosevelt and of Mr. Bernard M. Baruch in him and in his work in this field that encouraged him to return to the United States in 1929 and ultimately to winning his citizenship in this country.

However, the immediate plans for work with mineral water did not develop and Baudisch worked at Yale and Harvard on photochemical reaction until 1934 when the Saratoga Springs Authority requested his services as Technical Consultant for the development of the "Saratoga Spa". After a year's travel and study in Europe, with the permission of the Saratoga Springs Commission, he returned to Saratoga Springs and continued in the work of developing this important health resort which, in 1937, known as the Simon Baruch Institute for Hydro-therapy and Balneology, made him Director of Research. He has continued in this position up to the time of his Florida visit.

There are many good reasons for believing that the scientific contributions made by Dr. Baudisch in the more than 200 technical papers which he has published in the field of photochemistry and magnetochemistry in their relation to fundamental biological processes and consequently to normal growth and health, alike, in plants, animals and man will continue to render high service to science for a very great many years to come.

FLORIDA'S WATER PROBLEM AS VIEWED BY A GEOLOGIST*

HERMAN GUNTER **

The science of agriculture or the art of cultivating the soil and raising products to supply human wants, is the foundation of civilization. Whatever else we may accomplish through science and industry, in the final analysis, we are dependent upon agriculture; for without it science could not develop and industry could not exist.

Agriculture, however, to be successfully practiced, is dependent on fertile or responsive soil, adequate water, and bounteous sunshine. Is any state in the Union more favorably situated with respect to all these requirements than our own State of Florida? We have responsive soils, some peculiarly adapted to the growth, not only of sugar cane and green vegetables of almost every kind, but also fruits in great variety and staple farm products. No state can boast of more plenteous sunshine with all of its health giving rays; and ordinarily, we also have adequate rainfall. But it is true that even with our usually adequate rainfall we are now seriously concerned about the inadequacy of our surface and ground waters which come from rainfall.

Could it be that we have been careless in the disposition of this abundant rainfall and negligent and unwise in utilizing and developing our water resources?

One of the chief factors contributing to our lowering ground and surface water supplies is the many drainage districts that have been established in the state. Beginning with the early reclamation projects of drainage and development in the Everglades, Florida has experienced a veritable rash of such organizations during the period 1905 to 1925. Outside the Everglades Drainage District with its many sub-districts, and adjacent districts, there were set up a total of over 60 drainage districts in nearly all parts of peninsular Florida.

To get some idea of the possible effects of these drainage districts on our ground and surface water supplies, we have gone over the records of these districts which are most readily available and I think some of the summarized information regarding them will be of interest.

Outside the large Everglades District with its total area of 4,477,810 acres there are approximately 635,000 acres in drainage districts along the Atlantic coast and St. Johns River; over 210,000 acres in similar districts in counties bordering the Gulf of Mexico coast, and about 290,000 acres of such developments in Central Florida counties, particularly Polk, Hillsborough, Seminole, and Orange counties. This is a total of over 1,100,000 acres in drainage districts outside the Everglades.

We found it difficult to determine the extent to which each district was drained, how many canals each had, and the amount of water carried

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* Address delivered before an evening meeting of the Society on December 7 prior to the general business meeting.

** Director, State Geological Survey, Tallahassee.

off by the canals. From figures compiled by the Federal Emergency Relief Administration obtained through the Florida State Planning Board, we estimate a total of over 200 miles of main canals and over 400 miles of lateral or field ditches in 19 central Florida districts alone. Moreover, since these central Florida districts cover about 290,000 acres, or about 450 square miles, if only one foot of water is drained off each acre per year, that would be a total of 290,000 acre feet of water discharged to rivers and streams that otherwise would have to some extent gone into the ground water storage.

One acre foot of water is equal to 325,851 gallons so 290,000 acre feet means approximately 95 billion gallons of water. It is probable that much more water than this has been diverted by drainage from the ground water supply. In fact, the authorized drainage districts are only a part of the picture, because many thousands of acres of farm land, pasturage, grove land, highway and urban developments have been drained outside the established drainage districts, and the extent of this drainage can be only roughly estimated.

However, the harmful effects of this excess drainage are becoming more and more apparent with the passing years, so that many persons once advocating drainage now realize that removal of surface water over large areas is not the last word in agricultural and allied developments in Florida. Water control measures should have gone hand in hand with drainage. In fact, and as most of you know, many drainage projects were started as land speculation and promotional schemes. In the more than 60 districts outside the Everglades totaling over 1,100,000 acres, only about 200,000 acres have ever been cultivated; and in only three districts outside the Everglades has cultivation been sufficiently profitable to liquidate the district bonds.

The financial failure of all but three drainage districts outside the Everglades and a total of $40,000,000 default on bonds in these districts are evidences of the lack of agriculutural soundness of most of these drainage projects. These might have been worth while undertakings if they had paid in terms of agricultural products, but now, since it is evident that most of them have failed, their usefulness should be questioned and their harmful effects considered.

We may conclude, therefore, that much of the surface drainage of lands in Florida has not only been harmful to our water supply but that this drainage also has not been economically sound or agriculturally worth while in most instances.

However, before concluding that excessive drainage has been largely responsible for our depleted water supplies we should examine prevailing climatic conditions to see if changes in rainfall are responsible for some of the recent lack of water.

Let us look at the Weather Bureau's record, comparing the last 52 years with the last 11 years:

	52 Years	*11 Years*
Average annual precipitation in Florida	52.76″	53.51″
In North Florida	53.30″	53.35″
In South Florida	52.22″	53.35″

This shows that there has been slightly more rainfall during the last 11 years and very little change in averages over long periods of years. Thus we shall have to consider shorter periods of time and smaller areas of the State to find significant variations in rainfall.

The main question is: what about rainfall in recent years? And where are rain deficiencies most likely to affect ground water as well as surface water and soil conditions? As is well known, in those parts of the State where limestone lies close to the surface, or where it is overlain by permeable material, the rainfall finds ready entrance to the underlying formations. However, in those areas where the surface soils effectively cover the limestone and pervious formations, the rainfall is retarded or is prevented from readily entering the subsurface formations. Thus it is we have the terms, areas of "recharge". The lake region of Florida is generally one of "recharge" or "intake". The Weather Bureau records of Gainesville, Ocala, Orlando, Lakeland, Davenport, Lake Alfred, and Bartow show the following:

During 1942-1943 there was 4.82 inches less rainfall than normal in 1942 and 2.92 inches less than normal in 1943. Also in 1944, during the first nine months there has been less than normal rainfall, the September record ending with a deficiency of this year.

Furthermore, in 1941, these same 7 stations recorded an excess of 7.33 inches. Thus we can conclude that the recent dry period only has extended over 2 years and 9 months. Similarly, further examination of the data would show other dry years and other wet years and that such cycles are very significant in evaluating the circumstances which cause decreases in water supply.

It seems probable, therefore, that short periods of deficient rainfall are one of the main causes of local dry conditions such as lower lake and stream levels, lower ground water tables and, in some cases, less artesian flow. But the gradual, long term decrease in any of these is not due to climate, but to other factors, among which is the deliberate drainage of large areas which has been the result of the many drainage districts developed in the past.

It would take much more data than is now available to the United States Geological Survey and the Florida Geological Survey to distinguish between the direct effects of dry climatic periods and the effects of drainage. We hope to accumulate these data more and more completely, and for this purpose we have asked for an increase in our budget for cooperation with the United States Geological Survey in their investigations of water conditions. However, it is not necessary to wait on these long term records and studies of water conditions to profit by our past observations. Some of these observations, although not actually founded on instrumental data, but recognized as facts, are the following:

1. A general lowering of the water table in many areas.
2. Drilling more irrigation wells to supply water to crops.
3. Lowered lake levels in some areas.

All these relationships point to the need of systematic water control measures. Since it will always be impossible to alter or manage the climate to any extent, most of this control must come from *better regulation and control in our drainage districts.*

A STATEWIDE APPROACH TO THE SOLUTION OF OUR WATER PROBLEMS*

Frank L. Holland **

Ladies and Gentlemen: I wish to assure you that it is a real pleasure for me to be with you this evening. I am sorry that it was not possible for me to be here and listen to the papers and discussions during the morning and afternoon especially since all were on the same general subject that I am scheduled to discuss with you this evening.

Apparently you have heard practically every angle of the water situation in Kissimmee Valley and other areas reviewed in detail from both the technical and practical point of view. While I have very little understanding of the technical aspects of the problem, I do feel in any event that we ought to get right down to good old "Garden English" so the people over the state and in the Legislature will know what we are talking about. It needs to be put in this sort of language so Mr. and Mrs. Florida and Mr. and Mrs. America will know what the technical people are talking about. Consequently I am pleased to see meetings such as you have held today for that is just what you are doing.

It seems there are several reasons for approaching the water problem here in Florida from a state-wide angle. Emphasis on certain areas have been indicated today. As to the benefits of state-wide action, let us take a look at the public health program. Starting back in the last century, it wasn't left to the members of the Cabinet, nor to the County Commissioners or City Commissioners when the public health was involved. Where the reputation and safety of our state was at stake a state-wide program was developed; and I don't know where our tourist business would be today if it had not been done.

Let us examine specific instances that relate more directly to agriculture. When the citrus canker threatened the citrus industry of this state did we see that problem turned over to some local board or commission? The appeal went to the Legislature and they set up the State Plant Board, which has never been under politics. It was set up to administer and enforce certain laws and deal with the various agencies involved in any particular situation. It has proven so indispensible that I am sure none of us would now want to live without it.

The livestock industry of this state is terribly concerned with the present water situation. They cannot have floods ruining the pastures and drowning the livestock at one time and fires destroying the grass and trees at another!

What did cattlemen do when they wanted to get rid of the cattle fever tick? An isolated attempt here and there and somewhere else? Some highly successful in local areas and in others complete flops? No. They went to the Legislature and got laws enacted to set up the State Livestock

* Address delivered before an evening meeting of the Society on December 7 prior to the general business meeting.

** Manager, Florida Agricultural Research Institute, Winter Haven, Florida.

Sanitary Board. Then the livestock industry could attack their problems on a broad, sound basis and work with the various agencies—State and Federal, from a fully cooperative point of view.

Consider the hog cholera serum. Do any of us think for a moment that the hog industry of Florida would be in the condition it is today if it were not for that? Do any of you think the dairymen, the cattlemen, the poultrymen and hog raisers of the State would want to go back to the days prior to the creation of the State Livestock Sanitary Board?

Thus it is obvious that there is a precedent in this state for meeting major, state-wide problems on a state-wide basis; and it has been successful. I am not talking about barber boards and beautician boards and eyebrow boards, etc., but major economic problems and the state-wide organizations that have been formed to do the bidding of the people in what has amounted to definite crises in the past; and they have been very worthwhile, indispensably so in each instance; and we certainly would not want to go back to the days before we had them.

You are here in this series of meetings because, in your judgment, water is exceedingly important and we should be looking into the factors and forces that are producing the situation we are already facing in the matter of supply in various parts of the State.

Now, what are some of the reasons why we might consider meeting this water situation from a state-wide point of view? Take the scope of it. You know what it is. Mr. Gunter has ably discussed it from the geologic viewpoint. There are indeed many evidences of its being a state-wide matter. I cannot go into all of them now except to point out a few things.

It seems to me that the time has very definitely arrived for approaching this problem from the state-wide point of view. Take the rivers of upper Florida, for instance. Most of those of any importance originate in another state. Down here in this location and on to the south we think in terms of "Peninsular Florida" and that is but another reason for looking at the whole problem from a state-wide point of view; for the local and regional problems within the State are definitely interlocking. A further reason and a most outstanding one is the responsibility of the State. The State of Florida must be responsible to and for all of its people. It cannot properly and fairly ignore the problems of any group in the State, regardless of where they are. If our water problem is preventing us from being successful or may do so at some future time when the demand for it will be infinitely greater than at present, it is the duty of the State to do what it can to correct the situation.

Some reference was made to the fertile soils of Florida. However, most of our citrus is grown on soils where the lake waters help keep the weather mild in winter time—it is deep sand, and must be fertilized frequently. The only really significant difference between much of that land and the Sahara Desert is water. If that doesn't have any economic significance from the standpoint of the citrus industry, then I am a Monkey's Uncle.

Let us also take a look at the tourist business. It is the largest single income we have. Can you envision this increasingly vast number of people coming to a sand desert? When they think of coming to Florida they think of our climate, and fishing and boating and swimming and

other sports; and all these things must be thought of and planned for in terms of water.

The tourist industry is a really tremendous activity in this State and if we don't do something definite about it, it will decline and pass. Can we stand another 100 years of management of our water resources with the rate of loss experienced during the last 25 or 50 years?

There are thus, definite economic angles to this water question. You have heard about industry. Let us take the citrus and vegetable industries. In their canning and processing work alone they use tremendous volumes of water. They are processing a much bigger percentage each year. Last year, during the busy season, they were using millions of gallons of water every day. The same is true of the requirements of our mining industries. And what about air-conditioning, which is just getting started. I don't know where it is going to stop. The overall demand is increasing in a way and to an extent we didn't dream of 20 years ago. From a purely economic and industrial point of view there is again, then, the necessity for a state-wide approach to the problem. Thus it would appear that the State would be negligent, indeed, not to do something about the water situation when her whole bank account is at stake.

I would like to comment briefly on still another angle. Some other states are making tremendous progress along the line of water conservation and management, and so increasing their cultivated acreage. They have ambitious plans for extending their agricultural production in the post-war period; and that undoubtedly will take place. Two of those particular areas are competitors of Peninsular Florida. So that is another reason why the State should make plans to aid us in our efforts to improve agricultural production, knowing that other sections are making ready to out-produce us if they can do so.

It seems to me, in talking about state-wide projects, we should take a good look at what some of the other states have done, if anything. Quite a number have done something, some of them quite a bit; and others have done nothing, something like ourselves. You can always put your finger on the map and in 8 out of 10 cases, if they are progressive, they have done something about their water problems.

In this connection there are two groups I would like to refer to briefly. One group is up in the western part of the upper section of Michigan—the Michigan-Minnesota area. They have a large number of lakes. In this respect the area is very comparable to central Florida.

I will also have to refer to California. If any one state has really gone to town in this water matter, it is California. California started off as a small strip with the Pacific on one side and with mountains and deserts on the other; and a few fertile valleys in between. Her original water legislation goes back to 1866. Up to 1921, however, nothing much had been done to handle the situation from a state-wide approach; and at that time they decided on the state-wide approach—that is, not to administer everything from Sacramento; but everybody working together to solve and manage their problem.

As most of you know they have what is called a Water Project Authority in California that has to do with major projects. In other words this state-wide Authority has administrative responsibility for the major problems and projects—not the small items coming up in counties and

municipalities. These are taken care of by a Water Board. It is the Water Project Authority that has full responsibility in the big deals.

I have here a little folder which our California friends have gotten out which shows something of what is being done. Two hundred twenty-eight million dollars are being spent in control against drought by the U. S. Department of the Interior thru its Bureau of Reclamation. While their specific plan, as such, may not fit into Florida's needs, something else will. They found Federal funds the answer. This booklet tells about many other projects of the same general nature.

There is one specific instance of what has been accomplished in another state on a project which I would like to mention briefly. I wish there were time to go into some of these things in greater detail. I am referring to certain of these items because, by changing a few words here and there they sound almost exactly like what we are up against here in Florida today.

I would like to quote you some figures that have to do with a project in California. This is a statement of the Federal funds made available up to January 1, 1942—$149,969,000. California didn't leave the securing of those funds to the officials of random counties and municipalities. They made their plans, set up an organization and went to Washington. This is a further indication that if Florida is to get the necessary aid, she must have a state-wide plan.

Permit me again to emphasize that most of the states that are making progress with their water problems are going about it thru carefully coordinated state-wide planning. Most of them have set up what might be called Water Boards—some call them by one name, and some by another. Some of the most progressive states have a water code. Quite a few of these states have pretty rigid regulations about such matters as the building of railroad trestles and bridges in the construction of water control facilities of any sort. Thus the Highway Departments, County and State, must submit plans and get approval before they can do anything. You may be sure that the folks in those states where this work is going on have not lost their fruit or vegetable industries or various other industries. Not only do they still have them, but have more and better plans laid out in that regard for the future.

In closing I would like to emphasize and re-emphasize one more particular reason why state-wide planning is desirable. Reference is to the protection of every citizen's rights. All of us who have had any discussion with friends and neighbors about water matters, invariably hear someone express the idea that the thing to do in this state is to flood the pastures so the citrus boys can get along; and the next man is just the reverse. Those are extreme instances, but they do point to the necessity of a state-wide approach to the matter—an honest-to-goodness getting together. This applies especially well to the drainage district situation Dr. Gunter referred to just a few minutes ago. Some are good but many are bad. Proper planning in advance could have saved a tremendous load of bonded indebtedness. It is my feeling that your state-wide approach is the logical solution and the one that will be most helpful and certain in the long run.

CHAIRMAN VOLK:

The meeting is now open for general discussion.

Mr. Harold Scott:

I would like to add a few words from the U. S. Army Engineer's viewpoint.

As I said this afternoon, the improvements provided by the Federal Government must be economically justified. In the instance of one report I am working on, when I came to our recommendation, for we have to state what contribution or proportion of the expenses can be expected from the local interests, I found that in this instance there was no organization which could tell us that they would contribute certain rights of way or certain amounts of money or make up the difference between what we could feel was economically justified and the cost of the project. So we could not make a favorable report.

With such an organization as you are talking of the people of Florida would be in a position to work closely with us and when the point of definite recommendations is reached, if we are short certain funds, we could go to this organization and ask them if they could afford to supply this amount and thus make up the difference. I am sure such an organization would be in a position to say "yes" or "no". If it was to be a real benefit to the people of Florida I am sure the answer would be "yes". The point is that these improvements that are needed in Florida would be much easier to provide if a state-wide organization were available to work with.

SYMPOSIUM: NATURAL FACTORS AFFECTING WATER CONSERVATION AND FLOOD CONTROL IN THE KISSIMMEE VALLEY

THE SURFACE WATER RESOURCES OF THE KISSIMMEE RIVER BASIN

G. E. Ferguson *

INTRODUCTION

In contributions to earlier publications of the Society [1] the writer in discussing the surface water resources of the Everglades included those of the Kissimmee River basin because of the major dependency of the Everglades upon waters from this source. The waters of the Kissimmee River basin are, of course, also of great importance to those living or operating in the basin and this paper is directed to their interests as well as to those pertinent to the Lake Okeechobee and Everglades areas.

The waters of the Kissimmee River basin, like those of other river basins, are in a state of constant change both as to the volume in the basin and as to the rates of gain or loss. The rate at which the basin receives water (as rainfall) is highly variable as is the rate at which water is lost to the atmosphere and discharged out of the basin. The study of such variations and their characteristics is in the field of hydrology—the science of the occurrence of water in the earth—and is not only valuable but indispensable to those charged with the responsibility of changing or controlling the water conditions to permit successful development in the Kissimmee Valley.

Hydrologic studies of this basin recently have been made using basic records of rainfall, evaporation and stream flow. Rainfall records which have been collected for many years at several locations in and adjacent to the basin were furnished largely by the United States Weather Bureau. Water losses from standard types of evaporation pans were furnished by several Federal and State agencies. The stream flow records were collected by the United States Geological Survey in cooperation with the Okeechobee Flood Control District from 1931 to 1937 and with the Corps of Engineers, U. S. Army, from 1937 to this date.

GENERAL DRAINAGE PATTERN

The Kissimmee River drains an area of about 3,300 square miles bounded by the St. Johns River basin on the north and east and the

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* District Engineer, United States Geological Survey, in charge of investigations of surface water resources of Florida since 1941. (See also Proceedings Soil Science Society of Florida, Vol. IV-A, p. 77, 1942.)

[1] The Plan and Progress of Recent Surface Water Studies in the Everglades, Proceedings Soil Science Society of Florida, Vol. IV-A, pp. 77-85, 1942 and Summary of Three Years of Surface Water Studies in the Everglades, Vol. V-A, pp. 18-23, 1943.

Withlacoochee River, Peace Creek and Fisheating Creek basins on the west. It flows generally south and discharges into Lake Okeechobee. The basin may be considered in two distinct parts: the upper basin, which has an area of about 1,850 square miles and lies upstream from, but includes, Lake Kissimmee, and the lower basin consisting of the remaining area extending to Lake Okeechobee.

The upper basin contains in the aggregate about 200 square miles of lake surface, many of the larger lakes being interconnected by drainage canals through which water moves into Lake Kissimmee. The lower basin may in turn be divided into two parts. One is the Kissimmee valley proper, through which the River follows a well defined but meandering channel from Lake Kissimmee to Lake Okeechobee. The second part lies to the west and comprises an area of approximately 660 square miles drained by Arbuckle Creek into Lake Istokpoga and thence through Istokpoga Canal into the Kissimmee River.

A relatively small portion of the run-off from the upper basin is discharged northward during wet periods through a canal into the Econlockhatchee River, a tributary to the St. Johns River basin.

RAINFALL

The average annual rainfall over the Kissimmee River basin is about 50 inches, this being sufficient water to fill a hole a mile long, a mile wide and over two and a half miles deep! This average compares closely with the State average of about 53 inches but is materially greater than the average of 29 inches for the entire continental United States.

As we all know, the rainfall in the Kissimmee River basin is not evenly distributed throughout the year; over half of the annual total falls, on the average, in the four months of June, July, August and September. The distribution pattern may vary widely for any particular year. The average rainfall apparently does not vary greatly over different parts of the basin. However, over so large an area it is common to find drought conditions in one locality while another receives heavy recharge from storm rainfall.

RUN-OFF

Run-off is the term applied to that water which leaves a basin through surface channels. The run-off from the upper Kissimmee basin is measured as it passes out of Lake Kissimmee into the Kissimmee River. Similar measurements made near the mouth of the River at Lake Okeechobee determine the run-off from the entire basin. These measurements show certain conditions which are both interesting to the layman and valuable to those engaged in developing the water resources of the basin or in utilizing the waters discharged out of that area. How much of the water falling on the Kissimmee River basin is discharged into Lake Okeechobee? Do all parts of the basin give up equal amounts of this water? How does this run-off compare with adjacent basins? These are questions which can now be answered by an analysis of the hydrologic data already collected in the basin.

During the period 1931-32, inclusive, the run-off from the basin, as measured in the Kissimmee River near its point of discharge into Lake Okeechobee. was only 14 percent of the 50-inch average annual rainfall.

Comparison with other basins and of the several subdivisions of the Kissimmee River basin can best be made through an inspection of annual average run-off values for the period 1935-43, inclusive, when a greater number of stream-measuring stations were in operation. These are as follows:

Drainage Basin	*Drainage Area in Square Miles*	*Run-Off in Inches Over Area 1935-43*
Kissimmee River below Lake Kissimmee	1,850	6.6
Kissimmee River near Okeechobee	3,260	6.8
Istokpoga Canal near Cornwell	660	8 7
St. Johns River near Christmas	Approx. 1,500	10 8
Peace River at Arcadia	1,380	11.8

It is evident from the above results that the upper basin and the lower basin proper have a somewhat similar run-off factor, the latter being slightly higher since it includes the 660-square-mile basin drained by Arbuckle Creek and Istokpoga Canal which has a relatively high value. It is further seen that the run-off from the Kissimmee River basin is considerably less than that from both the upper St. Johns River basin and the Peace River basin. It is likely that differences in rainfall do not fully account for this disparity since topographic, geologic, and ecologic conditions are also important factors influencing this relationship.

The rates of run-off are comparatively low. It takes about three and a half months for the first half of the run-off from heavy storm rainfall to leave the basin and nearly nine months for a recession from highest to lowest rate of discharge. The lowest flows occur in the winter and spring, that for the month of May being, on the average, the lowest.

EVAPORATION

That water losses in the basin are relatively high is seen in the earlier statement that the run-off for an extended period amounted to only 14 percent of the rainfall. A very large part of the remaining 86 percent is lost to the atmosphere by evaporation from free water surfaces (rivers, ponds and lakes), from the ground and from the surface of the leaves of vegetation (transpiration). It is a little-realized but important fact that the atmosphere receives and discharges from four to six times as much water as the waterways.

For the 12-year period 1931-42 the mean annual difference between rainfall and run-off was over 42 inches for the entire basin. This value compares closely with the average annual losses from lake surfaces, as calculated for the same period from evaporation-pan records.

The rate of water loss to the atmosphere varies with the availability of the water, temperature, wind, relative humidity and solar radiation. Such loss from lake surfaces is usually greatest in May when the wind-temperature combination is most effective. The loss averages about 5 inches for that month. During the winter months of December and January, such loss drops to an average of about two inches per month. The loss from land areas is more complex in its constitution but likely follows a somewhat similar seasonal trend when moisture is available to the atmosphere.

The foregoing remarks are based on but a few of the hydrologic characteristics made known by the systematic observations and measure-

ments of the waters of the Kissimmee River basin. This program has been recently expanded under the Survey's cooperative program with the Corps of Engineers, U. S. Army, and now includes the collection of records of stage of the more important lakes in the upper basin and the measurements of amounts of water leaving these lakes through the drainage canals. The data collected are available to the public at the Survey's office at Ocala.

Chairman Volk:

Are there any questions?

Question:

Isn't some of the rainfall taken up by vertical leaching?

Mr. Ferguson:

Some of it is. There is probably some loss, as Mr. Parker will relate. How much water goes vertically into the ground, no one knows, but the question will be answered, generally, by Mr. Parker.

Question:

That evaporation is from the open water basins, not the water used by the trees and grass and crops?

Mr. Ferguson:

I mean total evaporation, which includes transpiration. A great deal goes to plant surfaces—85 percent in the long run.

GEOLOGY AND GROUND WATER OF THE KISSIMMEE RIVER-LAKE OKEECHOBEE AREA, FLORIDA

Garald G. Parker* and Nevin D. Hoy*

INTRODUCTION

Location

The area covered in this report is that part of peninsular Florida drained by the Kissimmee River and its tributaries. It also includes Lake Okeechobee and parts of the Counties of Orange, Polk, Osceola, Okeechobee, Highlands, Glades, Hendry, Palm Beach, and Martin (see maps, figures 1 and 2).

Present Investigation

Since the autumn of 1939 the U. S. Geological Survey has been cooperating with Miami, Miami Beach, Coral Gables, Dade County, and the Florida Geological Survey in a comprehensive water resources investigation of southeastern Florida. This work has largely centered in Dade County but has included geologic and hydrologic research in the Everglades and Big Cypress Swamp. Both surficial and sub-surface geologic and hydrologic studies have been made.

In 1942 the U. S. Geological Survey and Soil Conservation Service cooperated in a joint investigation of the ground water in the shallow aquifers (about 100 feet deep) in the Everglades. Fifteen exploratory test wells were drilled and valuable information was obtained.[1]

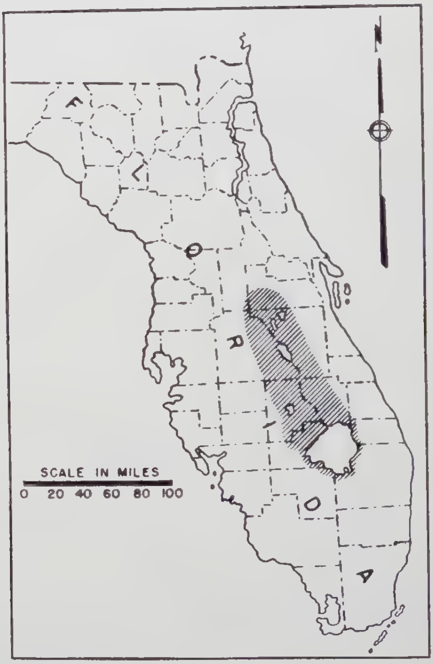

Figure 1.—Index Map of the Kissimmee River - Lake Okeechobee Area.

It has long been a local belief that a considerable amount of water in Lake Okeechobee and the Everglades is derived as ground water seepage from the geologic formations that underlie the Kissimmee

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* Geologist and Asst. Geologist, respectively, Geological Survey, U. S. Dept. of the Interior, Miami.

[1] Parker, Garald G., and N. D. Hoy. Additional notes on the geology and ground water of the Everglades in southern Florida, Soil Sci. Soc. of Fla., Proc. Vol. V-A (1943), pp. 33-55; 77-94, 1945.

River watershed, but Wallace,[2] in 1940, had come to the tentative conclusion, as a result of a short-time study of Lake Okeechobee hydrology, that there is probably no substantial loss or gain of water by the Lake through underground flow. In order to determine roughly the magnitude of this ground water flow and to obtain information on the geology of the formations involved, the U. S. Geological Survey and Soil Conservation Service in 1943 made areal geologic reconnaissance studies and drilled 14 exploratory test wells in this area; nine of these wells were located around the shores of Lake Okeechobee and five were in the lower Kissimmee River watershed and adjacent areas. (See map figure 2.)

In the meantime Ferguson[3] corroborated Wallace's tentative conclusions. By continuing the studies that Wallace began and by draw-

Figure 2.—Map showing contours of the piezometric surface of the principle artesian aquifer, and location of diagnostic wells.

[2] Cross, W. P., S. K. Love, G. G. Parker, and D. S. Wallace. Progress report on the investigation of water resources in southeastern, Florida, U. S. Geol. Surv. mimeographed report, text in Vol. I, illustrations in Vol. 2: Vol. 1, p. 19, 1940.

[3] Ferguson, George E. Summary of three years of surface water studies in the Everglades, Soil Sci. Soc. of Fla., Proc. Vol. V-A (1943), pp. 21-22, 1945.

ing up a hydrologic "balance sheet" for Lake Okeechobee he showed that a close agreement exists between water gains and losses in the Lake, but that the loss appears to exceed the gain by about 4 inches per year over the Lake basin, or about 550 acre feet per day. He points out, however, that inaccuracies in evaluating the actual losses in transpiration and evaporation may account for errors which may be sufficiently large to either cancel or more than double the net loss indicated.

In addition to the test well drilling, studies were made of the logs and cuttings of all wells in the area of which a record exists in the files of the Florida Geological Survey. Surprisingly, very few records have been obtained from the Kissimmee Valley, therefore the geology of the area is still imperfectly known. Most of the geologic data obtained are of the late Cenozoic era, and concern the shallowly buried formations, the topography, and the geologic history of that time.

It is the purpose of this report to give an account of the geologic and hydrologic conditions known as a result of this investigation and from previous work done in the general area. Unfortunately, no detailed research has been carried out in the middle and upper parts of the watershed, therefore it is impossible to make a comprehensive report.

Previous Investigations

A comprehensive study of the geology and ground water of the Kissimee River Valley has never been made, however, some data have been gathered and are published in several papers, listed below. This compilation is not exhaustive but it does include the most important references; the arrangement is chronological.

(1) Matson, G. C., and Samuel Sanford, Geology and Ground Waters of Florida, U. S. Geol. Surv. Water-Supply Paper 319, 1913.

(2) Sellards, E. H., and Herman Gunter. The artesian water supply of Eastern and Southern Florida, Florida Geol. Surv. Fifth Annual Report, 1913.

(3) Cushman, Joseph A. Age of the underlying rocks of Florida, Florida Geol. Surv. 12th Annual Report, 1919.

(4) Cushman, Joseph A. Foraminifera from the deep wells of Florida, Florida Geol. Surv. 13th Annual Report, 1921.

(5) Mossom, Stuart. Review of the structure and stratigraphy of Florida, Florida Geol. Surv. 17th Annual Report, 1926.

(6) Collins, W. D., and C. S. Howard. Chemical character of waters of Florida, U. S. Geol. Surv. Water-Supply Paper 596-G, 1928.

(7) Cooke, C. Wythe, and Stuart Mossom. Geology of Florida, 20th Annual Report, 1928.

(8) Leverett, Frank. The Pensacola terrace and associated beaches and bars in Florida, Florida Geol. Surv. Bulletin 7, 1931.

(9) Cushman, Joseph A., and G. M. Ponton. The foraminifera of the Upper, Middle and part of the Lower Miocene, Florida Geol. Surv. Bulletin 9, 1932.

(10) Stringfield, V. T. Ground water in the Lake Okeechobee area, Florida. Florida Geol. Surv. Report of Investigations 2, 1933.

(11) Stringfield, V. T. Artesian water in the Florida Peninsula, U. S. Geol. Surv. Water-Supply Paper 773-c, 1936.

(12) Cooke, C. Wythe. Scenery of Florida, Florida Geol. Surv. Bulletin 17, 1939.

(13) Davis, John H., Jr. Natural features of southern Florida, Florida Geol. Surv. Bulletin 25, 1943.

(14) Parker, Garald G., and C. Wythe Cooke. Late Cenozoic geology of southern Florida, Florida Geol. Surv. Bulletin 27, 1944.

(15) Unklesbay, A. G. Ground water conditions in Orlando and vicinity, Florida Geol. Surv. Report of Investigations No. 5, 1944.

(16) Parker, Garald G. The effect of the Pleistocene epoch on the geology and ground water of southern Florida, Fla. Acad. Sci. Quart. Jour., Vol. 8, No. 2, pp. 119-143, 1945.

(17) Cooke, C. Wythe. Geology of Florida, Florida Geol. Surv. Bulletin 29, 1945.

The reports by Stringfield on the Okeechobee area and by Unklesbay on Orlando and vicinity deal with areas lying to the south and north of the Kissimmee Valley respectively. These two papers are the only ones of the above list that report local investigations of ground water.

The Florida Geological Survey is the agency principally responsible for gathering what geologic data are known of the Kissimmee Valley. Since its organization in 1907 the Survey has collected, catalogued, filed and published data on the geology and ground water of the State of Florida, but has lacked the financial means of carrying out comprehensive investigations even though it has long been recognized that need for such work exists. Cooperation between the Florida Geological Survey and the U. S. Geological Survey has been responsible for much other collected and published data, especially for Matson's and Sanford's report, Stringfield's two reports and, with the aid of the U. S. Engineer Department, of Unklesbay's report.

Acknowledgments

The writers are indebted to many persons for help in the preparation of this report, especially to colleagues in the U. S. Geological Survey. Thanks are extended and appreciation expressed to O. E. Meinzer, V. T. Stringfield, and H. H. Cooper, Jr., for review and valuable criticisms; to S. Kenneth Love under whose supervision the water analyses were made by Margaret B. Thomas; to Julia A. Gardner who identified fossils; to Ross A. Ellwood who prepared the illustrations; and to Laura G. Pollard who typed the manuscript.

Grateful acknowledgment also is expressed to Herman Gunter, Director of the Florida Geological Survey, for his active assistance in furnishing data, laboratory facilities, and for critical review of the manuscript; to

C. Kay Davis and John C. Stephens of the U. S. Soil Conservation Service, without whose aid and active participation the field investigation could not have been made; and to R. V. Allison and A. P. Black of the University of Florida for their many helpful courtesies and encouragement in prosecuting the studies. Many others, including well drillers and local citizens who provided information on wells, have helped. To all those who have contributed in any way the authors are sincerely thankful.

GEOLOGY

General Statement

No attempt is made in this paper to describe completely the structure and stratigraphy of this area or to recount a complete geologic history. The oldest formations exposed at the surface are of Pleistocene age; these are marine terrace sands that completely cover the underlying formations and mask structure and stratigraphy rather effectively. Geologic data that may be gathered by areal reconnaissance include the nature of the surficial formations and the topography; little else can be learned. To determine the nature of the deeper formations it is necessary that a study of well cuttings and records be made.

In this area comparatively few wells have been drilled, either deep or shallow, and of the wells drilled, only a few are represented by carefully taken and preserved samples; therefore there has not been much opportunity to make an adequate study of sub-surface geology.

The writers have made reconnaissance surveys of the surficial geology, have carefully checked all published data, and have studied available well logs and cuttings. The present report is based on this work, and on the information gained by the drilling of 14 shallow test wells (see section of test well drilling, pp. 40-55).

The geology of southern Florida has been rather extensively treated in previous papers published by this Society,[4] [5] by the Florida Geological Survey,[6] and by the Florida Academy of Sciences;[7] therefore only a summary treatment is presented here.

Structural Geology

The area described in this report lies on the eastern and southern flanks of the Ocala anticline, which exposes rocks of the Ocala limestone at the surface about 150 feet above sea level in Marion County. From this high area the Ocala limestone dips seaward under younger geologic

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[4] Parker, Garald G. Notes on the geology and ground water of the Everglades in southern Florida, Proc. Soil Sci. Soc. Florida, IV-A, 1942 (1943); pp. 47-76.

[5] Parker, Garald G., and N. D. Hoy. Additional notes on the geology and ground water of the Everglades in southern Florida, Proc. Soil Sci. Soc. Florida, V-A, 1943 (1945); pp. 33-55, 77-94.

[6] Parker, Garald G., and C. Wythe Cooke. Late Cenozoic geology of southern Florida with a discussion of the ground water, Florida Geol. Sur. Bulletin 27; 119 pp., 4 figs., 26 pls.

[7] Parker, Garald G. Effect of the Pleistocene epoch on the geology and ground water of southern Florida, Florida Academy of Sciences Quarterly Journal, Volume 8, No. 2. 1945, pp. 119-143, 1945.

formations at comparatively gentle inclinations in all directions; the dip to the south is about five feet to the mile.[8]

This structure affords favorable conditions for the development of artesian pressure in the ground water not only of the older Cenozoic rocks but also of some of the younger ones. The deeper and older formations crop out on the floor of the Atlantic Ocean and the Gulf of Mexico; some probably crop out of the sides of the Floridian Plateau.[9]

In the Pliocene and Pleistocene formations of the Kissimmee River valley there are buried clayey and silty or marly beds of very low permeability that often have considerable areal extent and that slope to the east from the higher terrace lands. These confine water in local artesian aquifers which have a low pressure and are the sources of artesian water obtained from some of the shallow wells. The low pressure aquifers have never been mapped or studied in great detail. Some of them extend to the east under the Atlantic Coastal Ridge, and municipal supplies, such as that of Fort Pierce, are developed therefrom.

Effects of Events of the Late Cenozoic Era

Due to widespread crustal movements of the earth in late Pliocene time peninsular Florida emerged from the sea and probably was slightly tilted to the west. It is likely that these same crustal movements that elevated Florida also enlarged the oceanic basins and gave them greater capacity, thus causing a lowering of sea level. Cooke [10] and Stearns [11] have discussed this problem lucidly. At the close of the Pliocene epoch peninsular Florida probably stood several hundred feet above sea level.

During the Pleistocene, or Great Ice Age, peninsular Florida was repeatedly flooded and drained, probably largely in response to formation and dissolution of immense continental glaciers; and the ocean level was permanently lowered probably due to successive enlargement of the ocean basin in unstable parts of the earth's crust. Stearns [12] lists other factors that also may have been involved in the changing Pleistocene sea levels.

When the glaciers melted the sea stood high, and when the glaciers became large the sea stood low. The effects of this alternate forming and wasting of the continental glaciers reached far beyond the limits of the glaciers themselves and largely account for the present topography of Florida, especially of the southern part which includes the Kissimmee River - Lake Okeechobee area. Each high level sea brought with it salty water to the former fresh-water zone it had newly submerged, and eventually salt water seeped into and replaced the fresh water beneath the area encroached upon. Each low level sea allowed the recently ocean-covered land and underlying rocks to become exposed to fresh water, and

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[8] Parker, Garald G., and C. Wythe Cooke, *op. cit.* pp. 15-19, 1944.

[9] Vaughan, T. W. Contribution to the geologic history of the Floridian Plateau, Carnegie Inst. of Wash. Pub. No. 133, 1910.

[10] Cooke, C. Wythe. Geology of Florida, Florida Geol. Surv. Bulletin 29, pp. 245-248, 1945.

[11] Stearns, H. T. Eustatic shore lines of the Pacific, Geol. Soc. Am. Bulletin, volume 56, No. 11, pp. 1071-1077, 1945.

[12] Stearns, H. T., *op. cit.*, p. 1077.

the former sea bottom became a place where land plants and animals grew and flourished.

In areas where rocks were permeable enough for the rain water to penetrate, the residual sea water was first diluted, then eventually replaced with fresh water. In some instances the rocks were not permeable enough for flushing to take place, therefore even today pockets and lenses of this ancient sea water still exist in some places in southern Florida although somewhat modified by base-exchange processes and by dilution.[13] This accounts for the localities in the Kissimmee River - Lake Okeechobee area, the Everglades, and parts of the coastal areas of peninsular Florida where even shallow wells find only saline water.

The several stands of the Pleistocene sea above present sea level brought about the development of features peculiar to marine conditions that today give vivid proof of these former high sea levels. Old shore lines are in many place well preserved (Figures 3 and 4) and old bars, sand dunes, islands, lagoons, and tidal runways today are prominent features of the landscape, and often determine the economic uses of the land.

At the close of the Ice Age (perhaps 20,000 years ago) the ocean level began rising from a low stand of about —25 feet and today is probably still rising very slowly. With this rise in sea level came a slowing down in drainage from the interior of Florida and a rise in the water table, partly the result of a blocking of drainage brought about by bar-building and sand-filling of old discharge channels to the sea. This rise of water table and ponded conditions in the Everglades and Kissimmee Valley brought about the development of the extensive marl, peat, and muck soils so prized by agriculturists today.

Topography

General Statement.—Reference was made in the preceding section to the control that a fluctuating Pleistocene sea exerted over land forms and present land usage. In the following section the terraces formed by the eustatic changes in sea level during the Pleistocene epoch will be briefly described.

The marine terraces were formerly shallow sea bottoms on which were deposited sand, silt, shells and clay. Landward these deposits merge with estuarine and fluvatile deposits that were laid down in rivers emptying into the sea. These terraces are bordered along their inner margins by shore line features such as beach ridges, swales, off-shore and bay-bars, or, rarely, by low rocky sea cliffs notched by wave action.[14]

The surfaces of the terraces are generally almost featureless, flat, gently sloping plains with here and there an old sand bar or island remaining as slightly higher land. Old tidal runways are now the sites of rivers, creeks, or swamps, and the land surface is dissected by moving

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[13] Love, S. Kenneth. Cation exchange in ground water contaminated with sea water near Miami, Florida, Am. Geophysical Union Trans. of 1944, Part VI, pp. 951-955, 1945.

[14] Parker, Garald G. The effect of the Pleistocene epoch on the geology and ground water of southern Florida, Florida Acad. Sci. Quart. Jour. Vol. 8, No. 2, 1945, pp. 138-140.

Figure 3.—Talbot-Penholoway scarp east of Childs.

Figure 4.—Penholoway-Wicomico scarp north of Fort Drum.

water or pocked by the development of solution holes in underlying calcareous rocks. The wash of small waves in the water of the shallow ponds that often occupies these depressions and the circulation of wind-impelled currents tends to produce evenly-rounded shore lines. Swamps and lakes develop in the lower-lying, poorly drained areas of the terraces.

The terraces of southern Florida were first described by Matson,[15] who recognized three that he named Newberry, Tsala Apopka, and Pensacola, with shorelines of approximately 100, 60, and 40 feet above present sea level, respectively. The Pensacola, he noted, had a secondary division with a shoreline at about 20 feet. Matson did not have the advantage of the many topographic and aerial maps or the abundant lines of levels upon which to base his reports that the present writers have had.

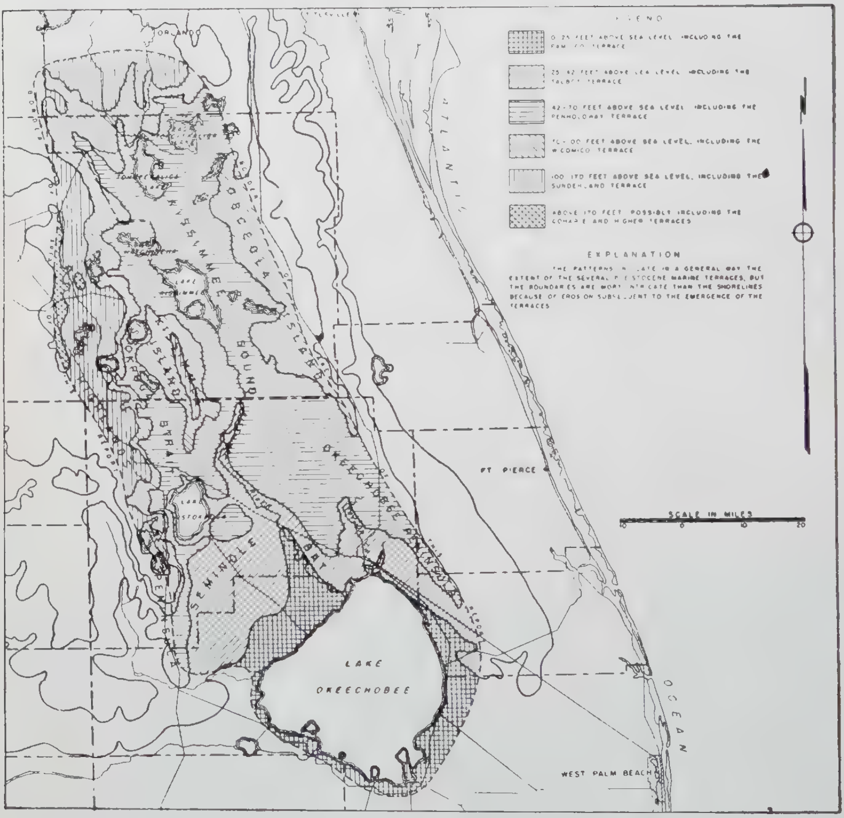

Figure 5.—Hypsometric map of Kissimmee River - Lake Okeechobee area.

Since Matson's investigations the terraces and their shorelines in Florida, and elsewhere in the world, have been studied by many geologists. Eight high-level shorelines have been described along the Atlantic sea-

[15] Matson, G. C. Geology and ground water of Florida, northern and central Florida, U. S. Geol. Surv. Water-Supply Paper 319, 1913, pp. 31-35.

board alone (Cooke,[16] Parker and Cooke[17]); and in Hawaii and the south Pacific Stearns[18] has detected four corresponding ones and several others that are not apparent in southeastern United States. In Cuba, Meinzer[19] has noted and briefly described the occurrence of seven Pleistocene marine terraces of which the one whose shore line is about 40 feet above present sea level is "most persistent and best preserved throughout the region." Meinzer notes that "the terraces consist largely of benches cut into the older rocks, and are mantled with soft, massive coral limestone."

In the Kissimmee River - Lake Okeechobee area the land surface elevations are usually less than 100 feet and by far the greater area lies between 70 and 15 feet (Lake Okeechobee shore line is about 15 feet). (See hypsometric map figure 5.) On the higher elevations to the west of the Kissimmee River valley, terraces higher than 170 feet (shore line of the Summerland terrace) are found, however, these high terrace deposits are very limited in extent. For the purposes of this report no description of these is needed, nor is it believed that detailed descriptions of the lower shore lines are desirable at the present time; they will be treated in a subsequent paper. Topographic features, however, will be described. Cooke[20] has assigned tentative ages to the several Pleistocene terraces; the following table for southeastern United States lists these, with the Miami shore line included:

PLEISTOCENE TERRACES OF SOUTHEASTERN UNITED STATES

Name	*Tentative Age*	*Altitude of Shore Line in Feet Above Sea Level (Approximate)*
Brandywine	Aftonian interglacial	270
Coharie	Yarmouth interglacial	215
Sunderland		170
Wicomico	Sangamon interglacial	100
Penholoway		70
Talbot		42
Pamlico	Wisconsin sub-interglacial	25
Miami		5

Sunderland Terrace.—Most of the central highlands area west of the Kissimmee River Valley is developed on the Sunderland terrace with some higher land possibly including the Coharie terrace. The Sunderland shore line on the west side of the Kissimmee watershed is short and approximately parallel to the trend of the Kissimmee Valley. The portion of the Sunderland terrace included in the Kissimmee watershed is narrow, averaging about 6 miles in width, and extends from the vicinity of Hicoria, in Highlands County, northward and eastward to a short distance south-

[16] Cooke, C. Wythe. Seven coastal terraces in the southeastern states, Wash. Acad. Sci. Jour vol. 21, 1931, pp. 503-515.

[17] Parker, Garald G., and C. Wythe Cooke. *Op. cit.*, pp. 20-27.

[18] Stearns, H. T. *Op. cit.*, pp. 1071-1077.

[19] Meinzer, O. E. Guantanamo Bay Reconnaissance, Wash. Acad. Sci. Jour., vol. 23, No. 5, 1933, pp. 256-258.

[20] Cooke, C. Wythe. Tentative ages of Pleistocene shore lines, Wash. Acad. Sci. Jour., vol. 25, 1935, pp. 331-333.

east of Orlando. (See figures 2 and 5.) In Sunderland time a long narrow peninsula was built southward from the main body of the terrace along the present western boundary of the Kissimmee Valley. To this Pleistocene peninsula, with its lower fringing terrace deposits, is given the name Highlands Peninsula, after Highland County (Figure 5).

Wicomico Terrace.—The inner boundary and shore line of the Wicomico terrace stands today approximately 100 feet above sea level, and its outer margin is bounded by the 70 foot shore line of the next younger terrace, the Penholoway.

The Wicomico terrace forms a narrow fringing band outside that part of the Sunderland terrace described above, and in addition forms the higher land along the eastern side of Kissimmee Valley where, in Wicomico time, a long-off-shore bar, here called Osceola Island, lay between deeper water of the Atlantic Ocean and the shallow water that extended about 20 miles west to the mainland. For this great Pleistocene shoal area the name Kissimmee Sound is here given. Osceola Island may have gained much of its modern shape during succeeding Penholoway time when it stood as an island about 70 miles long with an average width of about 6 miles. A long, narrow spit about 23 miles in length and a mile in width extended almost due north from the main body of Pleistocene Osceola Island to a point almost midway between the present-day cities of Orlando and Titusville. Osceola Island is important today as the drainage divide that separates the upper St. Johns' River Basin from the Kissimmee River Basin.

Another island of importance in Pleistocene Kissimmee Sound is here named Kissimmee Island (Figure 5). It was approximately 27 miles long and 8 miles wide, and today separates the larger Kissimmee River Valley from the smaller Arbuckle Creek Valley which drains southward into Lake Istokpoga and thence into Kissimmee River (Figure 2). In Wicomico time Kissimmee Island was separated from the mainland to the west by a salt water narrows, here called Istokpoga Strait, about 27 miles long and 3 miles wide. Kissimmee Island has a narrow core of land having elevations slightly above 100 feet altitude that may have been formed during Sunderland time but that also may represent a beach ridge of the Wicomico sea. Detailed study will be needed to determine this question.

Penholoway Terrace.—The 70 foot shoreline of the Penholoway terrace is fairly well preserved in places (Figure 4); it is usually marked by a wave-steepened slope, and, along the western side of Kissimmee Valley, by a scattering of sand dunes inland from its boundary. The terrace itself underlies most of the Kissimmee River Valley and is relatively broad, flat, and little dissected; it slopes gently to its outer margin where another terrace, the Talbot, with a shoreline at approximately 42 feet, borders it (Figure 3).

During Penholoway time Highlands Peninsula was lengthened and slightly broadened by long-shore currents sweeping southward as far as the present town of Palmdale, in Glades County. Fisheating Creek, not a part of the Kissimmee watershed, turns abruptly around the southern terminus of this extensive Pleistocene sand spit.

The Penholoway terrace is a narrow strip along the eastern side of Highlands Peninsula almost as far north as the southern shore of Lake

Istokpoga; there it widens to form a small peninsula. The outer terrace boundary skirts Lake Istokpoga then turns eastward across the Kissimmee River Valley with deep indentations upstream along Kissimmee River and Taylor Creek. To the south of Pleistocene Osceola Island the Penholoway terrace was built into a long peninsula extending to the northeast of Lake Okeechobee. To this Pleistocene marine feature is given the name Okeechobee Peninsula.

From Okeechobee Peninsula the Penholoway terrace extends northward in a band averaging about 7 miles wide fringing Osceola Island and generally paralleling the modern Atlantic shore. Small headward-working streams, tributary to the upper St. Johns Basin, scallop its outer (eastern) margin.

Kissimee River Basin: The present drainage system of the Kissimmee River with its numerous large and small lakes, its meandering channels connecting them, and its swampy lowland occupies Pleistocene Kissimmee Sound.

Rainfall and shallow ground water seepage from the adjacent higher terraces feed the Kissimmee River and it is this ground water seepage that maintains fairly uniform river flow even during dry seasons. Kissimmee River flows into Lake Okeechobee as the principal tributary. For details on the flow of this stream and the surface water characteristics of the drainage area see the preceding paper by George E. Ferguson (pp. 16-19).

Four large consequent lakes, Kissimmee, Hatchineha, Tohopekaliga, and East Tohopekaliga, occupy shallow basins that apparently were original depressions due to inequalities on the floor of Pleistocene Kissimmee Sound. Similar inequalities are noted today in the Bay of Florida, a comparable area. To what extent the lakes may be impounded by low sand bars is not known owing to lack of detailed topographic work. Some of the smaller lakes in the Kissimmee Valley are due to damning of the sluggish drainage ways by Recent organic material.

At the extreme northeastern corner of Pleistocene Kissimmee Sound there is a shallow but narrow strait connecting with the present St. Johns' River system between the northern extremity of Pleistocene Osceola Island and the mainland. In this area present surficial flow is indeterminate.

Talbot Terrace.—Following the 70 foot stand of the sea and the formation of the Penholoway terrace, the sea level dropped to about 42 feet and remained at that elevation long enough to form the Talbot terrace. Its outer limits are generally indefinitely marked in this area by the 25 foot stand of the Pamlico sea.

The inner shore line of the Talbot is marvelously preserved in some places, and may be viewed to good advantage 3 miles east of Childs on the Childs-Okeechobee Road, Florida Highway 18 (see Figure 3). There it lies at the foot of a noticeable wave-steepened scarp separating the Talbot and the Penholoway terraces. Inland from the old shore line lies a series of quiescent barchane-type dunes. Just east of the old shore line is a shallow off-shore trench beyond which lies an off-shore bar divided into islands by abandoned tidal channels. The old off-shore trench is now filled with a woody peat deposit (see John H. Davis vegetation map of this area in Bulletin 25 of Fla. Geol. Surv., 1943), and swamp vegetation grows there rankly. The old off-shore bar is known locally as the Parker Sand Islands.

The Talbot terrace in the Kissimmee watershed extends north of Lake Okeechobee to form the floor of a wide embayment, here called Pleistocene Seminole Bay, with a narrow projection extending up the Kissimmee River about as far as the north boundary of Highlands and Okeechobee Counties. An arm of the terrace also extends to the west and includes consequent Lake Istokpoga. East and northeast of Lake Okeechobee is the wide projection of Pleistocene Okeechobee Peninsula with a flanking strip of Talbot deposits around its core of Penholoway materials. Okeechobee Peninsula seems to have been formed in the same manner as the rest of these Pleistocene peninsulas, namely, by longshore currents dropping their load of sand in the form of a broad spit.

The Talbot terrace is remarkably flat, and drainage on it is very sluggish; sloughs, shallow ponds, and swamps abound. There are wide grassy plains with bunch grasses, palmettos, and pines as principal members of the flora.[21]

Pamlico Terrace.—During Pamlico time the sea level stood at 25 feet above the present level, and left an ill-defined shoreline that is usually marked by a change in slope of the present land surface. Only a small area of the Pamlico terrace is included in the Kissimmee watershed but Lake Okeechobee, into which the Kissimmee River flows, lies in an original depression on the Pamlico terrace.

The Pamlico is poorly drained; this is partly due to its flatness; partly to remnants of old beach ridges, bars, and swales that generally trend at right angles to the slope of the land surface; and partly to choking of drainage ways by an accumulation of organic materials such as peat and muck. The Everglades are entirely developed on the Pamlico terrace.

CHARACTERISTICS OF THE GEOLOGIC FORMATIONS

General Statement

In the area of this report water wells do not penetrate rocks deeper than the Eocene, and most of the deep wells end in the Ocala limestone of upper Eocene (Jackson) age. Some of the deep wells may terminate in the Oligocene (Suwannee limestone) or in the lower Miocene (Tampa limestone). This report is not concerned with rocks older than the Eocene, the epoch that marks the beginning of the Cenozoic era, and is principally concerned with the Pliocene and Pleistocene deposits, the ones penetrated in the 14 test wells reported herein.

The following table lists the formations encountered in drilling water wells in the Kissimme River - Lake Okeechobee area.

Eocene Series. Ocala and related limestones.—It has only been in the past few years that the Ocala limestone has been differentiated from the older Eocene rocks, and then mainly on the basis of the micro-faunas. In 1937 Stubbs [22] tentatively assigned a middle Eocene age to those rocks underlying typical Ocala limestone but which lack typical Ocala fossils and contain instead an abundance of the foraminifer *Dictyoconus cookei*

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[21] Davis, John H., Jr. The natural features of southern Florida, Florida Geol. Surv. Bulletin 29, 311 p., 71 figs., 5 maps, 1943.

[22] Stubbs, S. A. A study of the artesian water supply of Seminole County, Florida, Florida Acad. Sci. Proc. vol. 2, pp. 24-36, 1937.

TABLE 1.—FORMATIONS ENCOUNTERED IN DRILLING WATER WELLS IN THE KISSIMMEE RIVER-LAKE OKEECHOBEE AREA.

Age	Formation	Characteristics	Thickness in Feet
Recent and Pleistocene	Soils	Peat and muck	0-12?
	Lake Flirt marl	White to gray calcareous mud rich with shells of *Helisoma* sp., a fresh water gastropod. In places case-hardened to a dense limestone. Relatively impermeable	0-15?
Pleistocene	Undifferentiated terrace deposits	Principally unconsolidated quartz sands with intercalated clay and silt beds in places. Locally consolidated to a ferric sandstone. Generally permeable. Yields water to wells finished with a sand point	0-100?
	Fort Thompson formation	Alternating marine, brackish, and fresh water marls and limestones. Low permeability; a poor aquifer	0-16?
Pliocene	Caloosahatchee marl	Sandy shell marl, clay, silt and shell beds. Permeability generally very low. Yields some water, often under low artesian head but usually under water table conditions	0-100?
Miocene	Duplin marl	Shell marl, shelly sand, and clayey marl. A poor aquifer due to low permeability. Water is usually confined under low head	0-50?
	Hawthorn formation	Sandy phosphatic marl, interbedded with clay, shell marl, silt and sand. Greenish colors predominate. Contains beds of well-worn quartzite and phosphorite pebbles up to half inch in diameter, usually flattened. Water is limited and under low artesian pressure	50-500?
	Tampa limestone	White to tan, soft to hard, often partially recrystallized limestone. Yields artesian water but not so freely as lower rocks	150-250?
Oligocene	Suwannee limestone	Creamy, soft to hard limestone, similar to Ocala limestone beneath and probably often included with Ocala in earlier reports. Probably acts as a hydrologic unit with the Ocala in this area	0-200?
	Ocala limestone	White to cream, porous to dense, in part cherty, in part highly foraminiferal, limestone. An excellent artesian aquifer though the water is saline in some areas, especially in the Lake Okeechobee area and to the south	100-275?

TABLE 1.—FORMATIONS ENCOUNTERED IN DRILLING WATER WELLS IN THE KISSIMMEE RIVER-LAKE OKEECHOBEE AREA—(Concluded).

Age	Formation	Characteristics	Thickness in Feet
Eocene	Avon Park limestone	White to cream, foraminiferal limestone, with dark brown to tan crystalline to saccharoidal dolomite. Generally an excellent artesian aquifer yielding saline water in some places, especially in the Lake Okeechobee area and to the south	150-350?
	Lake City limestone	Dark brown dolomite and chalky limestone. Hydrologic characteristics imperfectly known	200-250?

(Moberg), which Stubbs identified as *Coskinolina* sp. To these rocks Stubbs gave the name "Coskinolina zone." Since then Cole [23] has divided the entire middle Eocene into seven zones, the youngest of which he calls the *Dictyoconus cookei* zone; and the Applins [24] have divided the middle Eocene into late, middle, and early middle ages, to which units several sub-surface geologic formation names are assigned. The Avon Park limestone of the Applins includes the *Dictyoconus cookei* zone of Cole, and their Lake City limestone includes his *Dictyoconus americanus* zone.

On the basis of sub-surface information Cole [25] has referred the Avon Park limestone to the Lisbon formation; and Erickson [26] has recently reported the discovery of surficial outcrops of this limestone in southern Levy and northern Citrus Counties. Because these exposures are well developed near the town of Gulf Hammock, Florida, Erickson has proposed the name "Gulf Hammock formation" to replace the term "Avon Park."

The Eocene rocks older than the Ocala contain a large amount of dolomite and dolomitic limestone with colors ranging from cream through tan to dark brown. Solution activity by circulating ground water in these calcareous rocks has developed caverns and a network of smaller channels and has made these formations very permeable. Until more deep wells are drilled and the cuttings studied the thickness of the middle and lower Eocene rocks will not be known in this area.

From the studies made of cuttings, and of fossils from deep wells that have been drilled in the area covered by this report, the following sum-

[23] Cole, W. Storrs. Stratigraphic and paleontologic studies of wells in Florida, Florida Geol. Surv. Bull. 19, 1941.

————. Stratigraphic and paleontologic studies of wells in Florida, No. 2, Florida Geol. Surv. Bull. 20.

[24] Applin, Paul L. and Esther R. Applin. Regional subsurface stratigraphy of Florida and Georgia, Am. Assoc. Petrol. Geol. Bull., vol. 28, No. 12, pp. 1673-1754, 1944.

[25] Cole, W. Storrs. Stratigraphic and paleontologic studies of wells in Florida, No. 3, Florida Geol. Surv. Bull. 26, 1944, pp. 25-26.

[26] Erickson, David B. The Gulf Hammock formation in Florida: Science, new ser., Vol. 102, No. 2644, p. 234, Aug. 31, 1945.

TABLE 2.—Formation Boundaries and Thickness in the Kissimmee River - Lake Okeechobee Area Based on Paleontologic and Lithologic Examination of Deep Well Cuttings.

Well Numbers Assigned by the Florida Geological Survey

(See Figure 2 for Well Locations)

Age	Formation	W-527 Depth	W-527 Th.	W-402 Depth	W-402 Th.	W-500 Depth	W-500 Th.	W-894 Depth	W-894 Th.	W-51 Depth	W-51 Th.	W-668 Depth	W-668 Th.	W-20 Depth	W-20 Th.
Recent and Pleistocene	Terrace sands	0 30+	30+	?	?	?	?	?	?	0 38	38	?	?	0 32	32
Pliocene	Caloosahatchee marl	absent ?		?	?	?	?	?	?	38 81	43	? 75	?	32 105	73
Miocene	Duplin marl	68 110	42	?	?	?	?	?	?	?	?	75 ?	?	105 175	70
	Hawthorn formation	110 230	120	140 ?	?	180 ?	?	130 515	385	81 468	387	230 325	95+	175 672	497
	Tampa limestone	absent ?		? 190	?	? 310	?	absent ?	- -	468 608	140	absent ?	—	672 800	128
Oligocene	Suwannee limestone	absent	—	absent	—	310 330	20	515 585	70	absent	....	absent	—	800 900	100
	Ocala limestone	230 260	30	190 290	100	330 540	210	585 930	345	608 775	167	325 600	275	900 970	70
	Avon Park limestone	260 410	150	290 ?	?	540 ?	?	930 1240	310			600 930	330	970 1332	362+
	Lake City limestone	410 1050	640	? 800	?	? 1063	?	1240 ?	?			930 1040	110+		

mary of formational boundaries and thicknesses is given. Because of lack of samples, or of lack of diagnostic fossils in the cuttings, many formational boundaries are impossible to determine. The locations of the wells are shown in Figure 2; for data on the quality of water see Table 7.

The Ocala limestone is generally a soft, white, highly foraminiferal, very permeable formation including some irregular hard cherty deposits. With the identification of the middle Eocene formations the former reported thickness of the Ocala must be revised. The greatest thickness noted in wells in the area of this report is 345 feet in W-894, at Sebring, and the least thickness is 30 feet in W-527 at Orlando. This variance in thickness is principally due to the fact that the upper surface of the Ocala has been eroded and is pitted with solution holes and sinks.

Oligocene Series. Suwannee limestone.—The Oligocene rocks are thin or in places missing entirely in the area of this report. Where present they are quite similar to the Ocala limestone and have been often included with them in well reports, owing to lack of diagnostic fossils.

Apparently the Suwannee limestone carries water under the same artesian pressure as does the Ocala and the two formations act as one hydrologic unit.

Miocene Series. Tampa limestone.—The oldest Miocene formation in this area is the Tampa limestone, surficial deposits of which occur 40 to 50 miles west of the upper Kissimmee Valley in Hillsboro, Pasco, and Pinellas counties. In its outcrop area the Tampa is a yellow to cream limestone, hard to soft and in some places silicious; it is permeable and an excellent aquifer.

In the area of this report the Tampa limestone is either absent or not recognized, in all but two wells; these are in the Lake Okeechobee area, not in the Kissimmee Valley. If the Tampa limestone was not deposited in the Kissimmee Valley area the shore line of the sea during Tampa time lay not far to the north of present Lake Okeechobee. There is a possibility, however, that the Tampa sediments were deposited in the area of the Kissimmee Valley, but have since been removed by erosion and solution or have been so altered by solution and secondary mineralization that they are not now recognizable. The present writers are inclined to believe that the Kissimmee Valley was dry land during Tampa time.

Where present in the area of this report the Tampa limestone probably acts as a part of the principal artesian aquifer.

Hawthorn formation and Duplin marl.—The Hawthorn formation is composed principally of greenish silty or very fine sandy marl, including beds or layers of marine shells, shell marl, and a considerable amount of calcareous clay. Quartzite and phosphate pebbles, some as much as one-half inch in greatest diameter are not uncommon, and sharks teeth abound. Phosphatic, gray to white, sandy, granular limestone is common toward the base of the formation. The Hawthorn overlies unconformably the several older formations that it overlaps.

The Hawthorn sea apparently covered all of Florida and was fairly deep during the early and middle parts of Hawthorn time. Toward the close, however, the sea became very shallow and beds of marine mollusk shells indicating very shallow or near-shore conditions were deposited.

The deposits assigned to the Hawthorn formation in peninsular Florida may not—and probably do not—all belong there, for excellent and varied fossils from the Choctawhatchee formation (now called Duplin) have been reported from several wells; for example, U. S. Geological Survey exploratory test well G-188 [27] located 19 miles west of Miami. Unklesbay [28] in referring to this problem, says "A few of the wells in the County (Orange) penetrate 30 to 40 feet of shell marl immediately under the surficial sand. This marl contains mollusks and foraminifera which appear to be contemporaneous with Choctawhatchee forms, but proof of this age relationship will require detailed examination of many well cuttings. The shell marl may represent highly fossiliferous portions of the Hawthorn, or it may actually be a deposit of Choctawhatchee time. As the shell marl has been reported in only a few wells, its areal extent is not known." Unklesbay, therefore, tentatively assigns this marl to the Hawthorn.

The Choctawhatchee marl was restricted and then correlated with the Duplin marl of North Carolina by Cooke.[29] In the area of this report, and to the south, the Duplin is principally a sandy shell marl with intercalated beds of sand, silt, and marine shells. The colors are dominantly gray to greenish-gray, and the general appearance is very similar to that of the Caloosahatchee marl (Pliocene) which overlies it over a wide area in south Florida.

Permeability generally is low or extremely low in both the Hawthorn formation and Duplin marl. Except in the shell beds, occasional "shoestring" deposits of coarser sand, and some of the limestone layers, water is not available or is obtainable only in very limited quantities. Most of the water that is available is under low artesian pressure.

As a whole the Hawthorn formation acts as a confining layer to the principal artesian aquifer lying below it. The several hundred feet of silt, clay, very fine sand and other sediments that comprise the Hawthorn prevent the upward movement of water from the Ocala and related limestones, and retain zones of saline water in some parts of the area.

Pliocene Series. Caloosahatchee marl.—Presumably the Caloosahatchee marl underlies most of the area of this report although it is questionable how far it extends to the north in the Kissimmee River Valley. The Caloosahatchee was penetrated in all the exploratory test wells drilled in this area during the field work preceding this report.

The Caloosahatchee marl is dominantly a gray to grayish-green silty or very fine sandy marine shell marl with interbedded layers of clay and silt that in some areas are somewhat carbonaceous. In some places the Caloosahatchee is composed of cemented shells or sandy shell marl that has been changed to a sandy shelly limestone later altered and made more permeable by solution.

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[27] Parker, Garald G., and C. Wythe Cooke. Late Cenozoic Geology of southern Florida with a discussion of the Ground Water, Florida Geol. Surv. Bull. 27, p. 109, pl. 26, 1944.

[28] Unklesbay, A. G. Ground water conditions in Orlando and vicinity, Florida Geol. Surv. Report of Inv. No. 5, pp. 11-12, 1944.

[29] Cooke, C. Wythe. Geology of Florida, Florida Geol. Surv. Bull. 29, 11, 180-1, 1945.

Generally, the Caloosahatchee is of low to very low permeability and difficulty is often experienced in the development of small wells finished with sand points. Wells that end in the sandy limestone may have a high yield once the loose sand is cleared from the rocks surrounding the yielding area of the wells. In many places the Caloosahatchee marl contains zones of saline water left there, probably, by the high-level seas of the Pleistocene interglacial ages.[30]

Pleistocene Series. Terrace sands.—Inasmuch as the deposits laid down during a particular sea level may be considered as being all of the same age, and inasmuch as the several high-level stands of the sea during Pleistocene interglacial ages left deposits that floor the marine terraces built at those times, it has been considered proper to apply separate formational names to the several terrace deposits. This has been done in the past by Parker and Cooke [31] and by Cooke,[32] but is not followed here because it is impossible, in the field, to separate these terrace sands except on the basis of their respective altitudes. Since these terrace sands are all so similar it is believed best to group them together under one heading and consider them as one formation, realizing however, that several interglacial ages probably are represented.

Generally, the sands are white to gray at the surface and grade into tan, orange, and red below. In some places enough organic materials are admixed to make a mucky sand, and in other places enough iron oxide (limonite) is deposited around the sand grains to form a ferric sandstone.

Fossils are absent in terrace sands that lie at altitudes above the Pamlico terrace (25 feet) and although diligent search has been made in these higher terraces no fossils have been found. The sand grains are generally sharp to sub-rounded, non-frosted, and are characteristic of marine, not aeolian sand. If fossils ever were present in these higher terraces it seems probable that they were leached out by percolating acidic ground water (pH values of 4 to 6 are common in these sandy soils today).

In some places, notably the northern end of the area reported upon, the terrace deposits contain varying amounts of silt and clay. This reduces the permeability and in some areas makes it difficult to develop shallow water-table wells. Generally, however, small-diameter, sand-point-finished wells driven deep enough to get below dry-season low levels of the water table will furnish potable water the year around for domestic use. Batteries of such wells will yield water for public supply systems of small communities.

Fort Thompson formation.—The Fort Thompson formation is composed of alternating marine, brackish, and fresh water deposits having a total thickness of about 16 feet but averaging less than 10 feet. The formation does not extend very far into the Kissimmee River Valley but is best developed in the Caloosahatchee River Valley, the Lake Okeechobee basin, and the Everglades.

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[30] Parker, Garald G. Effect of the Pleistocene Epoch on the Geology and Ground Water of southern Florida, Florida Acad. Sci. Quart. Jour., vol. 8, No. 2, pp. 119-143, 1945.

[31] Parker, Garald G., and C. Wythe Cooke. *Op. cit.*, pp. 75-78, 1944.

[32] Cooke, C. Wythe. Geology of Florida, Florida Geol. Surv. Bull. 29, pp. 275-312, 1945.

Generally, it is of rather low permeability and like the underlying Caloosahatchee marl. in its less permeable portions carries zones of saline water.

Recent and Pleistocene Series. Lake Flirt marl.—Occurring widely in the Everglades and in the Lake Okeechobee area is a deposit of calcareous mud, in places hardened into a compact white limestone, called the Lake Flirt marl. This principally calcareous deposit is never more than a few feet thick, and where present in association with peat and muck, usually lies beneath the organic deposits and acts as an impermeable layer preventing the movement of ground water through it.

Organic soils.—The organic deposits of the area are the peats and mucks that fill the Lake Okeechobee - Everglades depression to varying depths of approximately 8 feet, and that occur in patches in the Kissimmee Valley. Probably some of these organic materials began forming in the poorly drained parts of higher terraces in pre-Wisconsin time, but the principal development was in Wisconsin and post-Wisconsin time.

These organic materials quickly impart a high color (tan to dark brown) and "swamp" taste to the water that comes into contact with them. Water does not move easily through these materials of low permeability.

TABLE 3.—DESCRIPTION OF TEST WELLS GS 16 TO 29 INCLUSIVE.

Well No.	Location	Date Completed	Depth (feet)	Diameter (inches)
GS 16	SW¼ SE¼ sec. 18, T. 34 S., R. 36 E. 40 feet east of the Florida East Coast Railway at the Fort Drum Railroad station. Okeechobee County	7-14-43	90	4
GS 17	SE¼ NW¼ sec. 19, T. 38 S., R. 35 E. North side of Florida Route 29, 0.15 mile east of Kissimmee River, Okeechobee County	7-20-43	131	4
GS 18	NW¼ SW¼ sec. 18, T. 39 S., R. 34 E. South side of Florida Route 29, 0.15 mile southwest of Indian Prairie Canal, Glades County	7-22-43	75	4
GS 19	NE¼ NE¼ sec. 36, T. 38 S., R. 36 E. West side Florida Route 194, 0.1 mile north of Martin County line, Okeechobee County	7-24-43	80	4
GS 20	SW¼ SW¼ sec. 31, T. 37 S., R. 31 E. North side Florida Route 8, 4.8 miles east of Childs, Highlands County	7-20-43	125	4
GS 21	Sec. 3, T. 36 S., R. 31 E. South side of Istokpoga Canal approximately 1 mile east of Lake Istokpoga	8-3-43	65	4
GS 22	Sec. 8, T 36 S., R. 33 E. South bank of Kissimmee River, 1.5 miles north of Fort Bassinger, Highlands County	8-6-43	101	4

TABLE 3.—Description of Test Wells GS 16 to 29 Inclusive—(Concluded).

Well No.	Location	Date Completed	Depth (feet)	Diameter (inches)
GS 23	Sec. 23, T. 40 S., R. 40 E. North side Florida Route 29, 8.5 miles south of St. Lucie Canal, Martin County	8-12-43	90.5	4
GS 24	SE¼ SW¼ sec. 14, T. 41 S., R. 41 E. 200 feet east of Florida Route 143 and 3.6 miles north of Canal Point, Palm Beach County	8-16-43	70	4
GS 25	Sec. 20, T. 42 S., R. 37 E. 0.3 mile east of Florida Route 143 and 2 miles south of Pahokee, Palm Beach County	8-19-43	59	4
GS 26	T. 42 S., R. 36 E. On northern tip of Kraemer Island, 8 miles northwest of Belle Glade, Palm Beach County	8-23-43	91.5	4
GS 27	Sec. 34, T. 43 S., R. 35 E. North side of Florida Route 25, 1 7 miles northwest of Lake Harbor, Palm Beach County	8-25-43	56.5	4
GS 28	NW¼ SE¼ sec. 11, T. 42 S., R. 32 E. 300 feet south of Glades County court house, Moore Haven	8-28-43	63	4
GS 29	Sec. 22, T. 40 S., R. 32 E. North side of Florida Route 29, 1 mile east of Lakeport, Glades County	9-1-43	75	4

TEST WELL DRILLING

General Statement

Test wells GS* 16 through 29 (see Tables 4 and 5) were drilled in critical areas of the lower Kissimmee valley and in a ring surrounding Lake Okeechobee. Fig. 2 is a map which shows the locations of these wells, and of other wells the cuttings or logs of which were examined in the laboratory and museum of the Florida Geological Survey and are reported upon in this paper.

All of the GS wells were four inches in diameter and were drilled to an average depth of 84 feet; maximum depth was 131 feet and the minimum depth was 59 feet.

The procedure used was that which had been devised by the U. S. Geological Survey in its previous test well drilling, and has been described by Parker and Hoy [33] in a previous report to this Society.

From the collected data the age of the formations penetrated could be determined, and correlations could be made with rocks of other areas; a rough idea of the permeability of the formations could be obtained,

* GS is a symbol denoting exploratory test wells drilled jointly by the U. S. Geological Survey and the Soil Conservation Service.

[33] Parker, Garald G., and N. D. Hoy. *Op. cit.*, pp. 45-49.

that is, whether the permeability is low, average, or high; and the quality of water could be determined. Actually, due to the pressure of other urgent duties all the data gathered have not been completely studied; for instance, it has not been possible to complete the studies of the paleontological data gathered, but this will be done in the future and the results published in a subsequent report. All of the water samples have been analyzed and the results are given in Tables 6 and 7.

Data from Test Wells.—Being limited both by funds and time available to do test well drilling, plans were made for obtaining water samples and information on the water-bearing characteristics of the materials penetrated, by the least expensive method. This method has been explained previously before this Society by Parker and Hoy.[34] It was not possible to conduct field permeability tests which are both expensive and time consuming, but which would have given definite figures expressed as coefficients of permeability. Meinzer [35] has defined the field coefficient of permeability as the rate of flow, in gallons a day, under prevailing conditions, through each foot of thickness of a given aquifer in a width of one mile, for each foot of hydraulic gradient.

In this report the terms used to described permeability are relative and do not connote precise measurement. In general, clay or clay-marl is considered relatively impermeable; a sandy silt through which water will move only with difficulty is considered of very low permeability; a material, such as coarse sand and shells through which water moves with ease is considered of high permeability; and so on. For the method of exploration used no other means of expressing permeability is available. On some samples laboratory values for permeability were derived by use of a permeameter, but this was done only when it was believed that the samples obtained were excellent representatives of the materials being tested. In most instances in this investigation cuttings derived from the small-diameter test wells are not truly representative of the formation penetrated, for shells make up a large part of the geologic section and these were usually comminuted by the drill bit, and clay and sand present among the coarser materials was often washed out during the drilling process.

Well logs, typical of this area, have been published previously by several authors whose works are listed on pp. 22 and 23 of this report. It is not believed necessary to publish herein any but the logs of the 14 GS wells drilled jointly by the U. S. Geological Survey and Soil Conservation Service. See pages 42 to 59 for these logs and a table of well locations.

GROUND WATER OCCURRENCE

General Principles

Ground Water and Surface Water Defined.—Water that occurs beneath the earth's surface is called ground water, and that which occurs above the surface in streams and lakes is called surface water. Generally, shallow ground water under water-table conditions and surface water are

[34] Parker, Garald G., and N. D. Hoy. *Op. cit.*, pp. 45-49.

[35] Meinzer, O. E. Hydrology, Physics of the Earth IX, First Ed., McGraw-Hill. N. Y., pp. 452-453, 1942.

TABLE 4.—LOGS OF TEST WELLS GS 16 TO 29 INCLUSIVE.

GS 16

Depth in Feet	Rock Description	Permeability	Water Samples				Remarks
			Date Collected	Depth Sample Taken (in Feet)	Temperature °F.	Chloride ppm	
			1943 July				
0-2.5	Quartz sand.	Fair					
2.5-5.5	Dark brown indurated carbonaceous sand (hard pan).	Very low					
5.5-20	Dark brown sand, medium. A thin layer of friable sandstone at bottom of section.	Low	12 12	6 20		8 6	
20-28.8	Light brown quartz sand, fine to medium.	Low					
28.8-57	Gray quartz sand, fine to medium at top and medium to coarse at bottom.	Low					
57-62	Gray quartz sand with thin lenses of clay.	Very low	14	62		10	
62-73	Gray coarse shelly sand.	Medium					
73-90	Gray sand shell marl.	Very low	14	90		10	

GS 17

0-6	Gray quartz sand, fine to medium. Lake Okeechobee beach ridge.	Medium					
6-9	Dark brown carbonaceous sand.	Very low					
9-12	Muck.	Very low					
12-29	Gray quartz sand, fine to medium, with 0.5 foot layer of plastic muck at —23 feet.	Low	16	14	79	4	Yielded 2 gpm from a sand point well at 14 feet.
29-53	Gray sand, shell marl.	Very low	16	35	79	45	
53-54.5	Gray sandy, shelly marl. (Shells principally *Pecten* sp.). A thin layer of hard brown fossiliferous limestone.	Very low	17	49	78	335	
54.5-75	Gray sandy shelly marl with enough phosphate present to give a peppered appearance. A few thin layers of shell exist in this section.	Very low	17	75	78	315	
75-81.3	Quartz sand, medium to coarse, and small amount of phosphate.	Medium	19	81.3	78	375	A small yield could be obtained from a screened well.
81.3-90.3	Marly quartz sand, medium to coarse with small amount of shell fragments.	Low	19	90.3		610	
90.3-110.5	Dark gray marly quartz sand, fine to medium.	Very low					
110.5-123	Light greenish-gray sandy, shelly marl.	Very low	20	123	78	828	
123-131	Greenish-gray, marly sand, fine to medium.	Very low	20	131	78	288	

TABLE 4.—(Continued).

GS 18

Depth in Feet	Rock Description	Permeability	Water Samples				Remarks
			Date Col-lected	Depth Sample Taken (in Feet)	Temper-ature °F.	Chloride ppm	
0-0.5	Black carbonaceous sand.	Low					
0.5-2.8	Quartz sand.	Medium					
2.8-6.8	Shell bed of marine fossils.	Medium					
6.8-30	Gray very sandy marl. Sand very fine. Few shells and soft pieces of calcareous sands one in the interval of 18 feet - 23 feet.	Low					
30-44	Gray to black shell beds with medium to coarse quartz sand.	Fair	21	35		195	Screened well could be developed with a small yield.
44-54	Gray sandy shell marl.	Low	22	50		212	
54-75	Light green, sticky, sandy, clayey marl. Sand very fine.	Very low	22	59		258	

GS 19

0-3.5	Quartz sand and fresh water snails. Lake Okeechobee shore ridge deposit.	Medium					
3.5-5	Muck.	Very low					
5-9	Quartz sand, marl, marine shell bed, and a thin layer of brown, fresh water limestone in this section from top to bottom.	Fair in shell beds	23	9		63	Pumped 15 gpm with 4 feet drawdown.
9-15	Sandy shell beds and lenses of fine quartz sand.	Low					
15-26	Gray sandy, shelly marl.	Very low	23	19	78	218	
26-35.5	Quartz sand, fine to medium, and shell.	Low					
35.5-46	Sandy shell bed with small percentage of marl.	Low					
46-49	Sandy shell marl.	Low	23	49	78	785	
49-66	Very sandy marl with few shell fragments.	Low					
66-80	Gray sticky sandy marl with few shells.	Very low	24	80		785	

TABLE 4.—(Continued).

GS 20

Depth in Feet	Rock Description	Permeability	Water Samples: Date Collected	Water Samples: Depth Sample Taken (in Feet)	Water Samples: Temperature °F.	Water Samples: Chloride ppm	Remarks
0-0.5	Black carbonaceous sand.	Low					
0.5-1.5	Gray quartz sand.	Medium					
1.5-13	Light brown quartz sand, medium to coarse, and thin lenses of sandy clay.	Very low					
13-32	Gray silty clay with thin layers of calcareous sandstone alternating with the clay from 24 - 32 feet.	Relatively impermeable					
32-42	Gray sandy limestone with a small amount of clay and phosphate pebbles.	Fair	27	37.5		5	At 37.5 feet pumped 20 gpm with drawdown of 2.6 feet.
42-67	Gray sandy clay with coarse sand and gravel. Clay content sufficient to keep an open hole. This section contained a few shells and phosphate pebbles, also a thin layer of calcareous sandstone.	Fair	28	45.5	72	4	Pumped at —45.5 feet 60 gpm with 18.5 feet drawdown.
			29	57	73	4	Pumped at —57 feet 20 gpm with 3 feet drawdown.
			29	65.5	73	4	Pumped at —65.5 feet 75 gpm with app. 19 feet drawdown.
67-70	Quartz sand, very fine to fine.	Low					
70-99	Gray friable calcareous sandstone with thin lenses of clay and beds of sand. Small amount of chalk and phosphate pebbles present.	Fair	30	99	73	4	Pumped at —99 feet 6 gpm with 13 feet drawdown. Low yield due partly to sand rising into the casing.

99-108	Soft calcareous sands'one and thin layers of sandy, shelly marl.	Low					
108-125	Green sandy marl.	Relatively impermeable	30	125		5	This sample probably represents water from above 108 feet.
			GS 21				
			1943 Aug.				
0-2.5	Black to reddish brown carbonaceous sand. Note: approximately 3 feet of gray quartz sand usually overlies the carbonaceous sand in this area.	Very low					
2.5-18.5	Gray clayey sand with layers of quartz sand.	Very low					
18.3-51.5	Quartz sand, fine to medium.	Low					
31.5-40	Greenish-gray plastic sandy clay.	Relatively impermeable					
40-46	Gray clayey sand.	Very low					
46-53	Quartz sand, fine to medium.	Low					
53-65	Green and gray clayey, sandy, shelly, marl.	Very low	3	65		60	

TABLE 4.—(Continued).

GS 22

Depth in Feet	Rock Description	Permeability	Water Samples: Date Collected	Water Samples: Depth Sample Taken (in Feet)	Water Samples: Temperature °F.	Water Samples: Chloride ppm	Remarks
0-2	Quartz sand.	Fair					
2-21	Reddish brown indurated sand. (Forms a ledge along the banks of the Kissimmee River in this area.)	Very low					
21-30	Gray fine quartz sand with a small amount of clay.	Low					
30-48	Dark gray sandy clay with lenses of medium to coarse clayey sand.	Very low					
48-59	Gray sandy shell marl.	Low	5	—53.5		9	Water is under low artesian pressure.
59-65	Green sandy marl.	Low					
65-85	Green, sandy shelly marl. The sand and shells are more abundant at the bottom. Shells principally *Pecten* sp., and barnacles. Small percent of phosphate.	Low	6	71.3		11	
85-101	Green clayey marl.	Relatively impermeable	9	—101		9	Sample contaminated by water added while drilling.

GS 23

0-3	Gray to black carbonaceous sand.	Low					
3-8	Marine shell bed at top and quartz sand at bottom.	Medium					
8-22	Porous calcareous sand.	Fair	9	12	78	12	Pumped at —12 feet 36 gpm with 5 feet drawdown. After 40 minutes a large amount of sand was still being pumped out. A screen well in this section would give a fair yield.
22-68	Gray shelly quartz sand, fine to medium. The shells are fragmental and are less abundant in lower part of section.	Low	10 11	28 58		20 32	
68-74	Dark gray marly shelly sand. Small amount of phosphate pebbles. Transition zone.	Low	12	71		35	
74-90.5	Dark gray very sandy shell marl.	Low	12	90.5		238	This section has lower permeability than the sections from 22 feet - 74 feet.

GS 24

0-12.5	Muck and peat.	Very low					
12.5-15	Dark gray marl with few shells.	Very low					
12-23.5	Hard, light gray limestone.	Fair	13	—23.5	76	325	Pumped 20 gpm with 1.3 feet drawdown at —23.5 feet. Water has strong H_2S odor.

TABLE 4.—(Continued).

Depth in Feet	Rock Description	Permeability	Water Samples				Remarks
			Date Collected	Depth Sample Taken (in Feet)	Temperature °F.	Chloride ppm	
23.5-43.3	Gray, friable, shelly calcareous sandstone with lenses and pockets of sand. A hard layer of calcareous sandstone exists between 31.5 feet and 37.3 feet.	Fairly high	13	—30.5	74	840	At —30.5 feet pumped 155 gpm with 14 feet drawdown. Water has strong H_2S odor.
		Fairly high	14	37.3	74	1010	At —37.3 feet pumped 225 gpm with 16 4 feet drawdown. Water has strong H_2S odor.
			14	—43.3	74	1350	At —43.3 feet pumped 215 gpm with 16 feet drawdown. Water has strong H_2S odor.
43.3-45	Gray, fine quartz sand and few shell fragments.	Low					
45-65	Shells and medium to coarse quartz sand. Shell content approximately 60 - 70%. Small amount of shelly calcareous sandstone.		16	52.6		800	Small yields could be obtained from screened wells developed in this section. Water sample probably was contaminated by water added while drilling.
			16	—60.5		445	
65-70	Light greenish-gray sandy, very low shelly marl.	Very low	16	—70		465	

GS 25

0-8	Muck and peat.	Very low					
8-9	Hard, creamy, fresh water limestone.	Low					
9-12.5	White, chalkish marl.	Low					
12.5-14.5	Dark gray, nodular limestone and some marl.	Fair	20	—14.5	76	760	At —14.5 feet pumped 70 gpm with 7 feet drawdown. Water has strong H_2S odor.
14.5-25	Gray shell marl with small amount of loose calcareous sandstone.	Low					
25-40	Hard, gray, shelly, calcareous sandstone. Very hard from 26.5 feet - 27 feet, and softer at bottom.	Fair	20	29.5	76	830	At —29.5 feet pumped 50 gpm with 6 feet drawdown.
40-82	Gray, sandy, shell marl and a very small amount of calcareous sandstone.	Fair	21 23	-41.7 —78.5	76	910 960	At 41.7 feet pumped 145 gpm with 13.6 feet drawdown. Most of the water was coming from the interval of 33 feet - 40 feet. Fair yields from screened wells could be developed in this section.

GS 26 *

GS 27

0-8.5	Muck and peat.	Very low					
8.5-9	Gray hardened fresh water marl.	Very low					

* Complete data for this well not furnished.

TABLE 4.—(Continued).

Depth in Feet	Rock Description	Permeability	Water Samples: Date Collected	Water Samples: Depth Sample Taken (in Feet)	Water Samples: Temperature °F.	Water Samples: Chloride ppm	Remarks
9-18.5	Gray shell marl with beds of shells containing little sand and marl. Both marine and fresh water fossils.	Low	25	—12.5	78	33	Pumped 40 gpm with 1 foot drawdown at —12.5 feet.
18.5-23.5	Gray, loose, shelly, calcareous sandstone, shell and sand.	Medium					
23.5-27.5	Fine quartz sand and shell.	Low					
27.5-46	Gray, marly sand with thin layers of friable calcareous sandstone in the interval 34 - 39.	Very low	25 25	—29 —39		36 215	
46-56	Shell beds containing varying amounts of sand and marl.	Low	25 25	—50 —56.5		198 1189	
			GS 28				
0-3	Peat.	Very low					
3-10	Quartz sand.	Medium					
10-14	Shell bed with large amount of sand.	Low					
14-17	Quartz sand and shell with some calcareous sandstone, but not enough to make open hole.	Low	27	—17		75	Would not yield water to a pitcher pump without the use of a screen.

TABLE 4.—(Continued).

17-50	White quartz sand. Fine to —28 feet and then medium to coarse to 50 feet with small amount of calcareous sandstone.	Low to medium	28	—47		280	Small yield could be obtained from screened wells developed between 28 feet - 50 feet.
50-63	Gray coarse shelly sand.	Medium	28	—63		112	Same yield could be obtained as between 28 feet - 50 feet.
			GS 29				
0-4	Quartz sand with a thin layer of peat at —3 feet. Lake Okeechobee beach sand.	Low to very low					Entire section sampled in this well is of low to very low permeability.
4-8	Muck and peat.						
8-11	Gray marly sand.						
11-28.4	Gray sandy marl with few shells.						
28.4-41.5	Light gray very sandy, shelly marl.		31	—33.7		218	
41.5-47.5	Quartz sand, fine to medium and shells.		Sept. 1943				
47.5-55.7	Light greenish-gray sandy shelly marl.		1	—51		258	
55.7-61.8	Light greenish-gray plastic silty marl. Few shell fragments.						
61.8-75	Gray, very shelly, sandy marl.		1	—75		270	

TABLE 5.—CHEMICAL ANALYSES (p.p.m.) BY U. S. GEOLOGICAL SURVEY OF WATER FROM EXPLORATORY TEST WELLS GS 16 TO 29 INCLUSIVE.

(See Table 3 for location and other data)

Well No.	Depth	Date	Specific Conductance (K x 10^5 at 25°C)	Color	pH	Temperature (°F)	Dissolved Solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and Potassium (Na+K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Total Hardness as $CaCO_3$
GS 16	5	7-12-43	7.7	850	5.6	....	48	....	.02	3.6	4.3	6.0	4.0	24	8	.3	27
GS 16	12.5	7-12-43	9.7	....	....	....	....	....	....	....	....	....	....	....	12	....	....
GS 16	19.9	7-12-43	4.4	175	6.6	....	37	....	.04	5.2	2.5	4.5	18	9.3	6	.2	23
GS 16	62	7-14-43	35.7	....	....	....	....	....	....	....	....	....	....	....	10	....	....
GS 16	90	7-14-43	46.3	20	7.5	....	255	....	.07	90	7.0	....	278	11	10	.1	254
GS 17	14	7-16-43	31.7	300	6.2	79	....	....	2.5	41	7.2	....	122	5	4	.0	132
GS 17	35	7-16-43	69.5	....	....	....	....	....	....	....	....	....	....	....	45	....	....
GS 17	49	7-17-43	206	38	7.0	78	1140	....	.08	184	3.1	225	730	5	335	.0	586
GS 17	75	7-17-43	....	....	....	....	....	....	....	....	....	....	....	....	315	....	....
GS 17	81.3	7-19-43	192	....	....	....	....	....	....	....	....	....	....	....	375	....	....
GS 17	90.3	7-19-43	307	35	7.5	....	1789	....	.04	120	38	501	470	288	610	.0	456
GS 17	123.2	7-20-43	176	....	....	....	....	....	....	....	....	....	....	....	828	....	....
GS 17	131	7-20-43	166	60	7.2	78	938	....	.15	92	24	233	376	116	288	.0	328
GS 18	35	7-21-43	154	80	7.3	....	904	....	.02	134	33	166	534	113	195	.2	470
GS 18	50	7-21-43	166	....	....	....	....	....	....	....	....	....	....	....	212	....	....
GS 18	59	7-21-43	179	....	....	....	....	....	....	....	....	....	....	....	258	....	....
GS 18	75	7-21-43	179	45	7.7	....	1041	....	.10	103	40	241	528	129	268	.0	422
GS 19	8 9	7-23-43	98.4	....	....	....	....	....	....	....	....	....	....	....	63	....	....
GS 19	19	7-23-43	155	55	7.0	78	915	....	.05	168	35	129	514	109	218	2.8	564
GS 19	49	7-23-43	304	32	7.5	....	1659	....	.03	139	55	424	392	63	785	....	573
GS 19	80	7-24-43	304	....	....	....	....	....	....	....	....	....	....	....	785	....	....
GS 20	37.5	7-27-43	15.0	3	8.3	....	75	....	.04	20	3.5	4.6	76	5	4.8	.0	64
GS 20	45.5	7-28-43	14.9	....	....	....	....	....	....	....	....	....	....	....	4.0	....	....
GS 20	57.5	7-29-43	13.5	....	....	73	....	....	....	....	....	....	....	....	4.0	....	....
GS 20	65.5	7-29-43	13.9	....	....	73	....	....	....	....	....	....	....	....	4.2	....	....
GS 20	99	7-30-43	14.6	....	....	73	....	....	....	....	....	....	....	....	4.5	....	....
GS 20	125	7-30-43	18.8	25	7.9	....	119	....	.04	28	3.7	12	102	20	5.2	.0	85
GS 21	65	8-3-43	64.9	15	7.4	....	354	....	.04	80	12	44	314	3	60	.4	249
GS 22	53.5	8-5-43	37.1	55	7.4	....	300	....	.04	70	5.5	44	332	7	9.0	.9	197
GS 22	71.3	8-6-43	39.6	....	....	....	....	....	....	....	....	....	....	....	11	....	....

TABLE 5—(Continued)

Well No.	Depth	Date	Specific Conductance (K x 10^5 at 25°C)	Color	pH	Temperature (°F)	Dissolved Solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and Potassium (Na+K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Total Hardness as $CaCO_3$
GS 22	101.2	8-6-43	27.0	90	7.6	....	142	....	.04	46	3.7	2.8	130	15	9.0	1.6	130
GS 23	12	8-9-43	56.1	....	....	78	....	....	....	....	....	....	....	....	12	....	....
GS 23	28	8-10-43	63.6	29	7.4	....	367	....	.05	127	4.8	7.6	356	31	20	.9	336
GS 23	58	8-11-43	41.3	....	....	....	....	....	....	....	....	....	....	....	32	....	....
GS 23	71	8-12-43	45.1	....	....	....	....	....	....	....	....	....	....	....	35	....	....
GS 23	90.5	8-12-43	156	12	7.2	....	920	....	.03	128	26	182	418	139	238	.6	426
GS 24	23.4	8-13-43	338	380	7.1	76	2209	....	.09	188	192	378	1470	400	325	1.5	1258
GS 24	30.5	8-13-43	479	380	7.1	74	3090	....	.0	157	200	758	1634	326	840	....	1214
GS 24	37.3	8-14-43	535	....	....	....	....	....	....	....	....	....	....	....	1010	....	....
GS 24	43.3	8-14-43	642	312	7.2	74	4030	....	.04	232	95	1222	1780	254	1350	....	970
GS 24	52.6	8-15-43	446	....	....	....	....	....	....	....	....	....	....	....	800	....	....
GS 24	60.5	8-16-43	315	55	7.2	....	1913	....	.08	154	123	404	1050	270	445	....	890
GS 24	70	8-16-43	312	....	....	....	....	....	....	....	....	....	....	....	465	....	....
GS 25	27	8-18-43	246	320	6.9	75	1530	....	.13	210	124	197	1120	231	215	....	1034
GS 25	45	8-18-43	306	252	7.0	75	4390	....	.20	204	103	1357	1155	267	1885	....	932
GS 25	59	8-19-43	454	....	....	....	....	....	....	....	....	....	....	....	780	....	....
GS 26	14.5	8-20-43	442	450	6.7	76	2870	....	.20	414	199	343	1050	639	760	....	1852
GS 26	29 5	8-20-43	430	....	....	76	....	....	....	....	....	....	....	....	830	....	....
GS 26	41.7	8-21-43	454	240	....	76	2780	....	.04	176	180	646	1305	221	910	....	1179
GS 26	78 5	8-23-43	487	95	....	....	2960	....	.06	184	152	685	640	667	960	....	1084
GS 26	91.5	8-23-43	473	....	7.0	....	....	....	....	....	....	....	852	....	910	....	....
GS 27	12.5	8-25-43	69.7	....	7.1	78	....	....	....	....	....	....	358	....	33	....	....
GS 27	29	8-25-43	58.3	23	7.4	....	305	....	.04	64	22	25	292	10	36	4.0	250
GS 27	39	8-25-43	161	33	7.5	....	922	....	.04	88	44	209	564	84	215	3.7	400
GS 27	50	8-25-43	141	....	7.4	....	....	....	....	....	....	....	460	....	198	....	....
GS 27	56 5	8-25-43	561	25	7.1	....	3500	....	.02	165	98	1013	882	605	1180	....	815
GS 28	17	8-28-43	109	65	7.4	....	631	....	.03	156	13	66	484	79	75	3.8	443
GS 28	47	8-28-43	95.4	90	7.0	....	852	....	.05	144	12	175	458	10	280	....	409
GS 28	63	8-28 43	115	42	7.1	....	691	....	.02	156	17	83	476	88	112	.2	460
GS 29	33.7	8-31-43	161	90	7.3	....	950	....	.06	174	31	135	464	154	218	9.6	562
GS 29	51	9-1-43	153	20	7.4	....	858	....	.07	78	36	201	384	96	258	.1	342
GS 29	75	9-1-43	160	....	7.4	....	....	....	....	....	....	....	374	....	270	....	....

TABLE 6.—DESCRIPTION OF WELLS (OTHER THAN GS WELLS) FOR WHICH DATA ARE GIVEN.
(For GS Wells See Tables 3, 4 and 5)

Note: Nos. 156-355 Inclusive Taken from U. S. Geological Survey Water Supply Paper 596-G, 1928

No.	Owner	Location	Depth in Feet	Diameter in Inches	Use
156	Florida Ice & Power Co.	Avon Park, Highlands County	1040	8	Public supply
157	City of Sebring	Sebring, Highlands County	150	13	Municipal supply
269	City of Okeechobee	Okeechobee, Okeechobee County	660	6	Municipal supply
270	Okeechobee Telephone Co.	Okeechobee, Okeechobee County	15	1¼	Supply
276	A. J. Nye	Orlando, Orange County	350		Supply
284	City of Kissimmee	Kissimmee, Osceola County	420 450	12	2 wells, municipal supply
285	Osceola County	Kissimmee, Osceola County	180	1½	Supply
286	City of St. Cloud	St. Cloud, Osceola County	625	10	Municipal supply
342	Frostproof Citrus Growers Association	Frostproof, Polk County	770	4	Public supply
344	Miss E. Dahm	Haines City, Polk County	42	1	Supply
345	V. C. Thompson	Haines City, Polk County	40	2	Supply
346	Florida Ice & Power Co.	Haines City, Polk County	600		Supply
350	Florida Ice & Power Co.	Lake Wales, Polk County	800	8	Public supply
355	City of Winter Haven	Winter Haven, Polk County	630	10	Municipal supply
S 1192	City of Okeechobee	Site of Okeechobee Water Plant. Lot 5, Block 134, Okeechobee, Okeechobee Co.	718	8-6	Abandoned public supply
S 1220	Mr. Spender	50 feet north of St. Lucie Canal and 150 feet south of Lake Okeechobee, Martin County	27	1¼	Abandoned supply

No.	Owner	Location	Depth in Feet	Diameter in Inches	Use
S 1206A	Bessemer Properties	SE¼ of NE¼ Sec. 13, T. 40 S., R. 37 E. Town of Port Mayaca, Martin County	32	4	Supply
S 1207	Town of Pahokee	Mayaca Cemetery. 120 feet south of Florida Route 109, and 2.3 miles east of Florida Route 194, Martin County	30	3	Irrigation
S 1241	Kautz Dairy	SW¼ of SW¼ Sec. 13, T. 40 S., R. 37 E., Martin County	40	2	Dairy supply
S 1242	Cuyler W. Hilliard	Well C, NE¼ of SE¼ Sec. 18, T. 36 S., R. 35 E., Okeechobee County	80	1¼	Stock supply
S 1243	Mr. Raulerson	Well D, SW¼ of SE¼, Sec. 19, T. 36 S., R. 36 E., Okeechobee County	95	1¼	Supply
S 1244	Dixie Cattle Ranch	Well E, NW¼ of NE¼, Sec. 21, T. 36 S., R. 34 E., Okeechobee County	996	6	Stock supply
W 20	University of Florida	Experiment Station, Belle Glade, Palm Beach County	1332	10-8	Abandoned supply
W 51	(Same as S 1192, see Table 7)				
W 402	City of Haines City	About 5 blocks northeast of Post Office, Sec. 28, T. 27 S., R. 27 E., Polk County	802.5	16	Municipal supply
W 500	Florida Public Service Co.	New water tank site, E½ Sec. 2, T. 30 S., R. 27 E., Lake Wales, Polk County	1063	18-12	Municipal supply
W 527	Florida Public Service Corporation	Site of Florida Public Service Corporation plant, Orlando, Orange County	1050	18-12	Supply
W 668	U. S. Army	Avon Park Bombing Range, Sec. 31, T. 32 S., R. 30 E., Polk County	1040		Supply
W 894	City of Sebring	At water works, Sebring, Highlands County	1278	12-10	Municipal supply

TABLE 7.—CHEMICAL ANALYSES (p.p.m.) BY U. S. GEOLOGICAL SURVEY OF WATER FROM TYPICAL WELLS OF THE KISSIMMEE RIVER - LAKE OKEECHOBEE AREA. (See Table 6 for location and other data)

Well No.	Depth	Date	Analyst	Specific Conductance (K x 10^5 at 25°C.)	Color	pH	Temperature (°F.)	Total Dissolved Solids at 180°C.	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and Potassium (Na+K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Total Hardness $CaCO_3$
156	1040	10-26-23	F	....	....	....	....	152	28	[2] 1.4	29	15	4.7	155	3.4	4.6	.75	134
157	150	2-13-24	F	....	....	....	....	32	7.1	.04	.5	1.8	{Na 4.1, K .7}	2.4	2.7	6.0	7.5	8.6
269	660	10-31-23	F	....	....	....	....	1300	19	.10	109	60	265	125	235	532	.77	518
270	15	10-31-23	F	....	....	....	....	114	6.1	[2] 4.8	3.2	3.0	16	17	12	13	Tr.	20
276	350	9-9-23	H	....	....	....	....	178	19	.05	40	9.7	13	161	2.3	13	1.0	140
284	Comp., 420-450	11-10-23	H	....	....	....	....	123	14	Tr.	30	5.9	5.5	120	3.9	5.5	Tr.	99
285	180	1-15-08	D	....	....	....	....	131	....	.1	30	6	[1] 11	[3] 137	2	6	....	100
286	625	11-10-23	H	....	....	....	....	242	23	[2] 1.0	48	8.7	10	142	41	8.5	Tr.	156
342	770	10-25-23	F	....	....	....	....	....	....	....	44	16	....	193	2.1	8.8	.75	176
344	42	9-30-24	H	....	....	....	....	99	3.6	.13	11	2.8	13	3.7	44	8.0	8.3	3.9
345	40	7-22-44	H	....	....	....	....	53	....	....	....	....	....	17	[5] 4	5.0	4.6	[6] 10
346	600	3-17-24	H	....	....	....	....	192	12	.09	51	4.5	13	189	3.5	12	Tr.	146
350	800	10-24-23	F	....	....	....	....	160	19	.13	38	12	2.8	160	3.2	6.2	.71	144
355	630	10-17-23	H	....	....	....	....	148	19	[2] .70	39	5.2	6.3	139	2.8	6.0	Tr.	119

TABLE 7.—(Continued).

Well No.	Depth	Date	Analyst	Specific Conductance (K x 10^5 at 25°C.)	Color	pH	Temperature (°F.)	Total Dissolved Solids at 180°C.	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and Potassium (Na+K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Total Hardness $CaCO_3$
1192	718	9-11-41	L	210	5	....	79	....	....	[4] .05	102	57	270	129	233	515	....	489
1200	27	9-12-41	L	80.2	140	....	77	....	....	[4] .4	148	19	6.7	489	39	10	8.2	447
1206	32	10-3-41	L	32.7	160	....	78	....	....	[4] .79	59	5.0	1.2	189	8.0	5	.1	168
1207	30	9-12-41	L	44.9	50	....	78	....	....	[4] .1	83	5.7	3.2	269	9.7	5	0	231
1241	40	10-3-41	L	88.7	150	....	76	....	....	[4] .91	124	10	51	396	24	79	.1	351
1242	80	10-3-41	L	59.2	15	....	75	....	....	[4] .1	103	6.6	12	344	2.1	19	0	284
1243	95	10-3-41	L	55.7	30	....	73	....	....	[4] .1	108	4.1	6.1	343	2.9	11	0	286
1244	996	10-3-41	L	142	20	....	80.5	....	....	[4] .2	62	42	156	120	160	285	....	327

NOTES:

[1] Calculated.
[2] Includes iron precipitated at time of analysis.
[3] Includes equivalent of small quantity of carbonate (CO_3).
[4] Iron in solution at time of analysis.
[5] By turbidity.
[6] Determined.
F—Margaret D. Foster.
H—C. S. Howard.
D—R. B. Dole.
L—S. Kenneth Love.
Analyses of wells 156 through 355 taken from U. S. Geological Survey Water Supply Paper 596-G, 1928.

closely related, and in the Kissimmee watershed no exception occurs, for the shallow ground water in many places seeps into lakes and streams thus helping to maintain fairly uniform stages and flows of surface water even though seasonal rainfall may vary considerably.

The Hydrologic Cycle.—Water evaporating into the air as vapor from open bodies of water or from moist land surfaces is joined with water that is transpired (breathed) into the air from plants and ascends to form clouds, which, when conditions are right, release the water as precipitation upon the earth below. This circulation of water from the earth's surface to the atmosphere and back again is called the hydrologic cycle.

The sandy nature of the soils and geologic formations of the Kissimmee watershed allow the rainfall to sink into the ground and become stored in the unseen and little known ground-water reservoirs of the area. All of the rain that falls, however, does not contribute to the underground reservoirs. Some is evaporated again before it sinks into the ground; some flows seaward through rivers and canals; some remains temporarily in lake basins; some is caught by plant rootlets and returned to the air as transpired water through the leaves of plants; what is left may eventually get down through the soil and contribute to the ground water. Thus, the hydrologic cycle is rather complex, for some particles of water return to the clouds again very soon after precipitation but others return again only after ages spent in the ground or ocean, and some, through chemical combination with minerals, may never return.

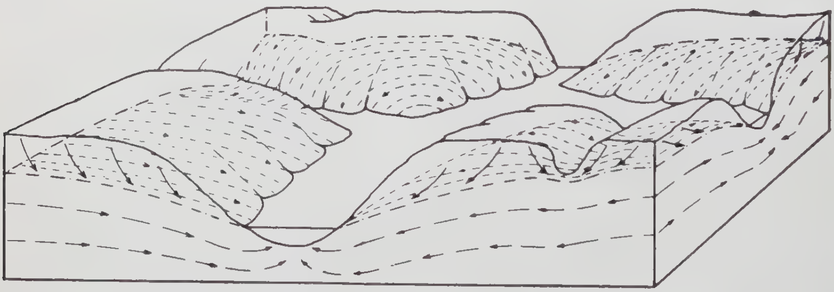

Figure 6.—Idealized block diagram showing relations of water table to land surface.

The Water Table—Unconfined Ground Water.—Water seeps into the ground and fills the spaces between the rock particles of the underground reservoir (aquifer) up to a certain height thus making a water-saturated zone; the upper surface of this saturated zone is called the water table. To many persons the term "water table" denotes a flat surface but actually it seldom is that. A glance at Figure 6, the block diagram, will show plainly what the term means. Note that the water table is higher under the hills than it is under the valleys; in general it reflects the topography of the land in a very subdued fashion.

The water table is a free surface, acted upon mainly by gravity and not at all by pressure such as exists in artesian aquifers (discussed below). Where the water table intersects the land surface, seeps or springs form, and if the topography is favorable, a marsh, lake, or stream may exist there.

In areas where the ground water resources are studied carefully, maps of the water table are prepared for certain selected times which show by contours on the water table the direction of flow of the unconfined ground water, the height of the ground water with reference to a common datum plane (such as mean sea level), and gives other valuable and pertinent data. No water table maps have ever been made of the area covered in this report.

The Piezometric Surface—Confined Ground Water.—When water seeps down into permeable rocks lying between relatively impermeable beds having the proper geologic structure it comes to be under hydrostatic pressure and will rise in wells penetrating the permeable beds to some point above the depth where the water was first encountered in drilling the well. In Figure 7, which represents a hypothetical area having a geologic structure similar to that of the Kissimmee Valley, aquifer A carries only non-artesian water, or water under water-table conditions. Layer B, a silty or clayey material, separates aquifer A from aquifer C, which, down-slope from the intake area, contains water under artesian pressure.

In the highland area, where the permeable beds outcrop, the artesian aquifer has a water table and the water that is not confined. Such an area is termed a "recharge area" for it is there that the aquifer receives its water. The recharge area is always higher than that part of the

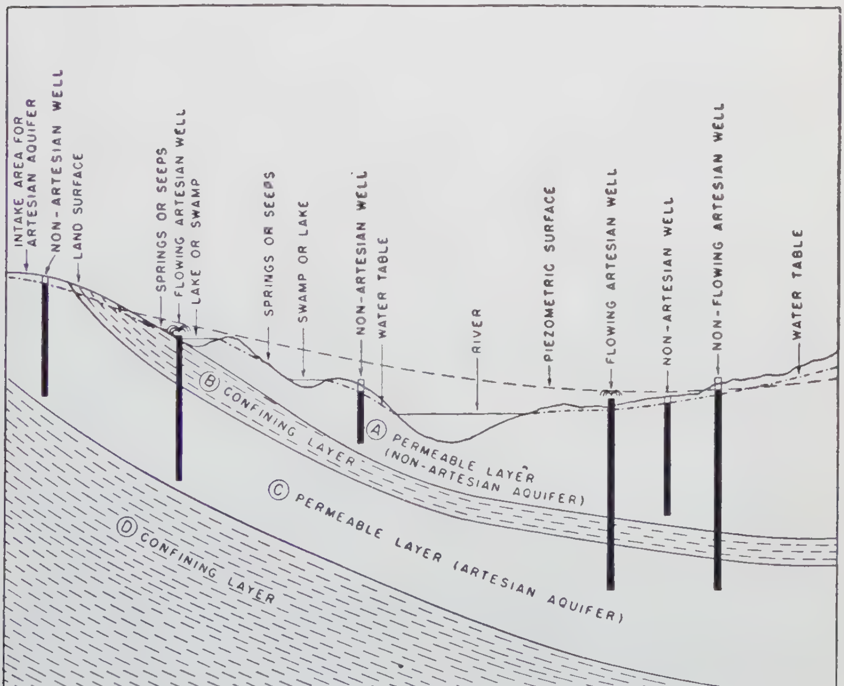

Figure 7.—Idealized cross section showing relation between water table and piezometric surface in an area having geologic structure similar to that of the Kissimmee Valley.

country where artesian wells are developed; were this not so there ordinarily would be no artesian wells for the water in these wells rises mainly because of the pressure exerted by the "head" of the ground water in the higher area. An exception to this rule would be artesian flow that is due to gas pressure or perhaps rock pressure. Thus an artesian aquifer is both an underground reservoir and a conduit under natural pressure. The water in it behaves somewhat as water does in a municipal water supply system.

When water is withdrawn from artesian wells, given adequate recharge, no unwatering of the artesian aquifer takes place but the pressure is lowered. On the contrary, when water is withdrawn from an aquifer under water-table conditions an actual unwatering of the aquifer occurs as the water table drops in response to pumpage.

An imaginary surface indicating the height to which water will rise in artesian wells represents the artesian head in any given artesian aquifer; it is called the piezometric surface and is to an artesian aquifer the counterpart of the water table to an unconfined aquifer.

By mapping the piezometric surface a great deal may be learned of the occurrence and behavior of water in an artesian aquifer. Fortunately, this has been done already in Florida by the U. S. Geological Survey in cooperation with the Florida Geological Survey,[36] and maps have been made showing the piezometric surface of the principal artesian aquifers, which, in the area of this report, are deeply buried. However, only a few local areas in Florida having shallow artesian aquifers have been mapped. Figure 2 is a map including the area of this report and shows the height above mean sea level to which water will rise in tightly cased wells which penetrate the principal artesian aquifers. The contours represent the piezometric surface and have an interval of 10 feet; the datum is mean sea level.

Ground Water in the Kissimmee River - Lake Okeechobee Area

Deep Aquifers.—As was pointed out in the discussion of characteristics of formations occurring in the area of this report (pp. 32-39) artesian water under relatively high pressure occurs in formations of Eocene, Oligocene, and early Miocene ages; and it is believed that these several formations generally act as one hydrologic unit in which artesian pressure is nearly uniform.[37] These rocks comprise the principal artesian aquifer.

Stringfield [38] has given an excellent account of this aquifer, has shown maps of the piezometric surface, areas of flow, and areas where mineralized water occurs, and in addition has listed much other useful information which includes actual well data. Because of his report it is believed that it will not be necessary here to go into detail on the deep artesian water of this area. Analyses of representative waters are given, however, in Tables 5 and 7, pp. 54-59.

In connection with the occurrence of salty water in the principal artesian aquifer it may be of more than passing interest to call attention

[36] Stringfield, V. T., Artesian Waters in the Florida Peninsula, U. S. Geol. Surv. Water Supply Paper 773-C, 1936.

[37] Stringfield, V. T., Artesian Waters in the Florida Peninsula, U. S. Geol. Surv. Water-Supply Paper 773-C, p. 134, 1936.

[38] Stringfield, V. T., *op. cit.*

to the close agreement between the location of the Pamlico and Talbot shore lines (25 and 42 feet above sea level, respectively) and the inner border of the area in which chloride of more than 100 parts per million is present at moderate depths (Figure 8). This may be mere coincidence, but it is believed by the writers that the saline water now in the aquifer is largely the diluted and somewhat chemically altered (principally by base-exchange) remnant of sea water that was introduced into the aquifer during the time of one or both of the last high level Pleistocene seas (Talbot and Pamlico).

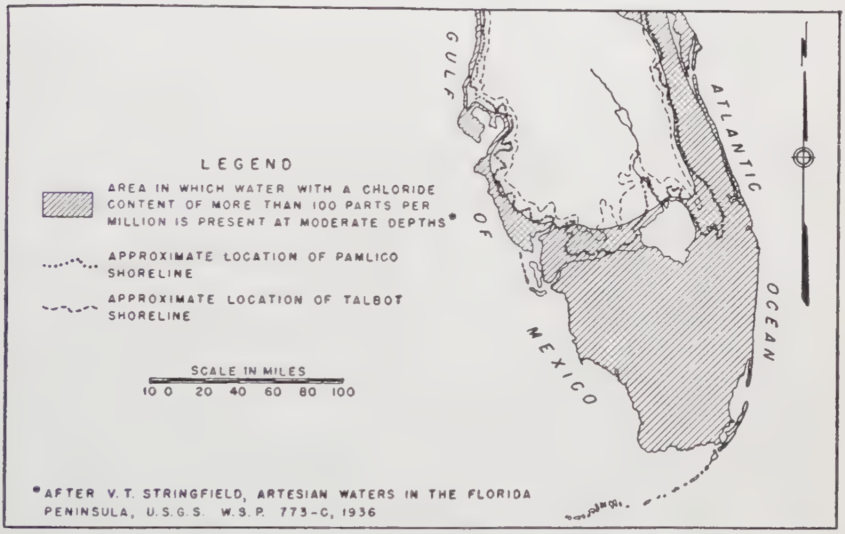

Figure 8.—Map of southern Florida showing relations between late Pleistocene shore lines and mineralized water in the principal artesian aquifer.

Stringfield [39] is of the opinion that such salt water encroachment took place in the St. Johns' River Valley where the artesian aquifer is not deeply buried. However, he considers that the conditions in southern Florida were not so favorable for encroachment and the described relation of the salt water in the deep artesian aquifer to the Pleistocene shore lines is probably coincidental.

Such sea water then, as now, had access to the aquifer through submarine outcrops of the permeable formations that comprise the aquifer and the distance that the sea water would penetrate inland before finally being arrested would be governed by the difference in head between the lighter fresh water on the land and the heavier salt water of the sea, according to the Ghyben-Herzberg principle.

This relationship between salt and fresh water was independently discovered by Badon Ghyben and A. Herzberg about 1900. In Holland in 1904 Pennick [40] convincingly demonstrated the application of the Ghyben-Herzberg theory. The results of the work of these men were

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[39] Stringfield, V. T., Personal communication, February, 1946.

[40] Pennick, J. M K., De "pris d'eau" der amsterdamsche duin waterleiding: K. Inst. Ing. Tijdschr, 1903-4, pp. 183-238, The Hague, 1904.

reviewed and application of their theory made to salt water encroachment along the coast of Connecticut by John S. Brown.[41]

Later workers, such as Stearns,[42] Wentworth,[43] Parker,[44] and Brown and Parker [45] have demonstrated that the Ghyben-Herzberg theory should no longer be classed as a theory but as a valid principle, and is applicable to coastal regions wherever salt and fresh water come into contact. Local geologic and hydrologic conditions must, of course, be taken into account.

The principle is too well known to require detailed exposition here. Suffice it to say simply that, in general, according to the Ghyben-Herzberg principle, one foot of head of fresh water above mean sea level indicates an additional 40 feet of fresh water below sea level, or stating it another way, that it would be 40 feet down to salt water. Given 3 feet of fresh water above mean sea level there would be 3 $\times$ 40 or 120 feet to salt water. Thus, if average fresh water level above mean sea level is known for any coastal area, the depth to salt water, allowing for limiting geologic and hydrologic factors, can be determined.

During the times of the last two high levels of the Pleistocene sea, when the ocean stood, respectively, at 40 and 25 feet above modern mean sea level, it is likely that the piezometric surface of the principal artesian aquifer in the area of this report did not differ greatly from that of today.

At the present time (see Figures 2 and 8) the piezometric head in the area of these late Pleistocene shore lines is about 50 to 60 feet above mean sea level. During the Pamlico and Talbot, if the piezometric head was comparable to that of today, the head in this same area would have been about 25 feet above Pamlico mean sea level (50 feet — 25 feet = 25 feet), and about 20 feet above Talbot mean sea level (60 feet — 40 feet = 20 feet). Applying the Ghyben-Herzberg principle to these fresh water heads, there would have been 40 $\times$ 25 feet or 1000 feet to salt water at the Pamlico shore, and 40 $\times$ 20 feet = 800 feet at the Talbot shore. Due to the slope of the land surface and the slight difference in sea level these shorelines were not far apart; thus their respective zones of equilibrium between salt and fresh water would have been close together. This makes it impossible to separate the zones today, but it may well account for the present location of salty water in the principal artesian aquifer.

For more complete discussions of salt water - fresh water relationships in Florida see the reports by Parker,[46] Brown and Parker,[47] and by Love.[48]

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[41] Brown, John S., A study of coastal ground water with special reference to Conn., USGS Water Supply Paper 537, pp. 17-19, 1925.

[42] Stearns, H. T., and K. N. Vaksvik, Geology and ground water resources of the Island of Oahu, Territory of Hawaii. Div. of Hydrography Bull. 1, p. 256, 1935.

[43] Wentworth, Chester K., The specific gravity of sea water and the Ghyben-Herzberg ratio at Honolulu. Univ. of Hawaii Bull., Occasional Paper No. 39, Vol. 18, No. 8, 24 pp., 1939.

[44] Parker, Garald G., Salt water encroachment in southern Florida. A.W.W.A., Jour., Vol. 37, No. 6, pp. 526-542, 1945.

[45] Brown, Russell H., and Garald G. Parker, Salt water encroachment in limestone at Silver Bluff, Miami, Florida, Econ. Geol. Vol. XL, No. 4, pp. 235-262, 1945.

[46] Parker, Garald G., *op. cit.*, pp. 526-542, 1924.

[47] Brown, R. H., and Garald G. Parker, *op. cit.*, pp. 235-262, 1945.

[48] Love, S Kenneth, Cation exchange in ground water contaminated with sea water near Miami, Florida, Am. Geophysical Union Trans. of 1944, Pt. VI, pp. 951-955, 1945.

Shallow Aquifers.—Formations down to and including the upper part of the Hawthorn formation are included in this category, and were the formations sampled in the 14 test wells. See pp. 39-55 for descriptions of these wells and data from them. As a general rule the permeability is low to very low (coefficient of permeability ranging from about 800 to 10), and it is concluded that below the upper layers of unconsolidated sand very little water makes its way underground from the high terrace lands bordering the lower Kissimmee River Valley directly into the basin of Lake Okeechobee.

The uppermost part of the unconfined aquifer is the chief contributor to stream flow in the area, and it is this thin mantle of terrace sand, generally one to twenty feet thick, that enables the Kissimmee River to maintain a fair volume of flow even during drouth periods.

The unconsolidated terrace sand borders Lake Okeechobee on the east, west, and north, for a total shore line distance of about 60 miles; but the sand contributes only relatively minor quantities of ground water during the course of a year's time to the Lake by direct seepage.

Assuming that the coefficient of permeability of the terrace sand bordering Lake Okeechobee is 800 (a figure which was obtained by making numerous permeameter tests of these sands); that the length of the section of such sands contributing ground water flow around the margin of the Lake is 60 miles (measured from a point about 6 miles south of Lakeport on the west shore to a point on the east shore about opposite Lakeport); that the average thickness of the permeable sand is 10 feet; and that the slope of the water table is 1.5 feet to the mile (about equivalent to land surface slope to the northwest as measured along Indian Prairie Canal) the amount of water that flows into the Lake may be computed by the following formula:

$$Q = Pf \cdot t \cdot l \cdot s.$$

Where Q = quantity of water in gallons a day.
Pf = field coefficient of permeability.
t = thickness of permeable aquifer in feet.
l = length of section of permeable aquifer in miles.
s = slope of water table in feet per mile.

Substituting numerical values for these factors:

$$Q = 800 \times 10 \times 60 \times 1.5$$

$Q = 720{,}000$ gallons per day or 1.1 second feet per day which is equivalent to about 730 acre feet per year—a relatively negligible amount.

While drilling the wells samples of the cuttings of the rock penetrated were collected every few feet, and water samples were collected whenever possible. Often the formations were without collectible water and in some cases it required overnight for enough water to seep into the well to be used for sampling purposes.

Also, it was found in several wells, notably those along the eastern and southern shores of Lake Okeechobee, that the ground water was highly mineralized and in some cases very highly colored. These conditions vouch for a very low rate of seepage through the formations for,

if much seepage ever did or now does occur, this water of poor quality should long ago have been flushed out.

In general, the quality of the water, as determined from the test wells, is poorest in the Caloosahatchee marl along the southern and southeastern shores of Lake Okeechobee, and is worse in the 40 to 50 feet intervals below land surface than at any other depth. This indicates sealed off zones of practically stagnant ground water, and some of it had a very disagreeable, stagnant odor. Highest chloride found in any of the samples of water from test wells was 1,885 parts per million at a depth of 45 feet (about —30 feet mean sea level) in GS-25, south of Pahokee.

Surprisingly enough, at no site around the Lake was ground water found, in the zone of maximum chloride, with less than 268 parts per million. Even in an area where it would be expected that chloride would be low, if anywhere (the mouth of Kissimmee River at Lake Okeechobee), it was found that the ground water was flushed of salinity only to a shallow depth. In GS-17, near the river's mouth, chloride was 4 parts per million at 14 feet (about lake bottom and 1.0 feet mean sea level): 335 parts per million at 49 feet; 610 parts per million at 90.3 feet and 228 parts per million at 131 feet. This indicates ground water flushing of the unconfined aquifer in this area at least as deep as the bottom of the lake but shows that below the lake bottom salinity is still comparatively high.

Highest color in ground water in the Lake area occurred in GS-26, on Kreamer Island, at a depth of only 14.5 feet or just about at the lake bottom, which is approximately mean sea level. In GS-24, north of Pahokee, a color of 380 was noted at —23.4 feet, or about 8 feet below the bottom of the lake; and in GS-25 a color of 320 was measured at a depth of 27 feet or about 12 feet below the bottom of Lake Okeechobee. Highest color in any of the GS wells was found at a depth of only 5 feet in GS-16, east of Fort Drum.

Farther up in the Kissimmee Valley flushing apparently was much better. It should be remembered, in considering mineralization of shallow ground water in the area of this report, that the area including the Pamlico terrace (which includes Lake Okeechobee) was most recently under the sea, and that a longer time has elapsed since the higher parts of the valley were inundated by the sea. This has allowed more time for these higher terrace deposits to be flushed of salt water. Also, Lake Okeechobee was a low area in the Pamlico sea bottom and with the retreat of the Pamlico sea was for some time a salty lake, thus the local topography—in addition to the lithology—aided in trapping saline water in this area.

Another factor in the irregular occurrence of ground water in the Lake Okeechobee area is the presence of buried Pliocene reefs and "shoestring" deposits of permeable sediments.

The ancient reefs are composed of calcareous sandstone or sandy, shelly limestone, and were carved out of the Caloosohatchee formation by wave and current erosion of the several Pleistocene high level seas. Although overlain by the Fort Thompson deposits and by Recent marls and mucks the reefs are very permeable and yield water freely to wells. The locations of these reefs are not mapped, but it is known that several of them exist in the southern part of the Lake Okeechobee area.

Initially the water that is developed from such ancient reefs may be low in dissolved mineral matter (the reefs were permeable enough to be flushed out by fresh water since the Pleistocene); but the reefs usually

are almost surrounded by materials of much lower permeability containing saline water. After pumping for a time the fresh water of the reef may be largely replaced by the surrounding saline water and the supply ruined.

In addition to these Caloosahatchee reefs there are a few "shoe-string" deposits of coarser materials, i.e., coarse sand, shells, or shelly sands that mark former ocean strand lines. These, now buried by later and denser materials, carry water of low mineralization at first, and when tapped by wells will yield freely. Like the reefs discussed above, they too may be exhausted of their fresh water, and yield only saline water drawn in and from surrounding materials. It is not an uncommon experience in the Lake Okeechobee area to find that a well which has been yielding potable water for a period of months or even years, suddenly becomes capable of yielding only salty water. Where such "reefs" or "shoe-string sands" have access to considerable fresh water recharge, such as a direct connection with Lake Okeechobee, they may continue to supply fresh, potable water indefinitely, even with comparatively heavy pumping. This is probably the case of several supplies located in the Bean City - Clewiston area and explains why these supplies remain as good as when first developed although some neighboring wells have become salty.

No opportunity has afforded itself for detailed field studies of either the shallow or the deep aquifers in the middle and northern parts of the area of this report. Matson and Sanford [49] gathered some data on these aquifers, and the following excerpts are given:

"In the interior of the State (of Florida) the head of the artesian waters is in places high. At Sanford it is approximately 25 feet above sea level and at Kissimmee is about 75 feet above, this probably being the maximum head in the State. The conditions at Kissimmee are exceptionally favorable, for dense materials above the limestone reenforce the cap rock and thus effectually prevent leakage, and to the south the limestones are so deeply covered that leakage is prevented. In addition to the flowing wells from the Vicksburgian (now recognized as the Ocala limestone, and in this report called "the principal artesian aquifer") the Quaternary and perhaps the younger Teritary furnish flowing wells near Kissimmee" (p. 237).

"In the vicinity of Kissimmee flowing wells are obtained from sands which are probably of Pleistocene age, though some of them may be Pliocene. Examples are to be seen in the shallower wells of the Lee-Parsons Cattle Co., and in some other shallow flowing wells near Kissimmee" (p. 254).

Although Matson and Sanford believed the Pleistocene of the Kissimme valley to be perhaps 200 feet deep, it is now recognized that these formations are seldom more than 50 feet thick in this area and perhaps generally considerably less than that. The shallow flowing wells were probably finished in the Pliocene (Caloosahatchee marl) and the Miocene (Duplin marl or Hawthorn formation).

Referring to wells and ground water in Osceola County, Matson and Sanford report (p. 380) "The Pleistocene sands are water-bearing in Osceola County and in many places furnish good supplies within a few feet of the surface. Both Pliocene and Miocene sands and marls probably

[49] Matson, G. C., and Samuel Sanford, Geology and ground waters of Florida, U. S. Geol. Surv. Water-Supply Paper 319, 1913.

yield abundant water, and some of the flows south of Kissimmee are believed to be furnished by these formations. . . . The water from the Pleistocene sand is soft. The beds of Pliocene and Miocene age and the Vicksburgian (principal artesian aquifer) limestones furnish water which is moderately hard and is usually salty. . . . At Kissimmee wells at 4 to 15 feet deep obtain water, and good supplies could probably be obtained in all parts of the county within 40 or 50 feet of the surface. Several deep wells are less than 150 feet in depth, and only a few wells exceed 300 feet. Good flows can be obtained where the surface does not rise more than 72 feet above sea level, and in some places flows have been obtained on slightly higher ground."

"Although no attempts have been made to procure flowing water near the southern end of the county, there is little doubt that flows could be obtained. The water, however, might be too saline for use. This is inferred from the fact that the salinity appears to increase toward the south, the wells south of Kissimmee containing much more salt than those at the town."

Although many wells have been drilled since Matson and Sanford did their work and Stringfield completed his field investigations preparatory to writing U. S. Geological Survey Water Supply Paper 773-C, little more actual data has been gathered in the northern and central parts of the Kissimmee River valley. The work that has been done in the southern part (as reported in this paper) should be expanded eventually to include the whole valley.

SUMMARY AND CONCLUSIONS

Although rather comprehensive studies of the geology and ground water have been made in the Orlando area and around Lake Okeechobee, which lie at the north and south ends of the Kissimmee Valley, respectively, none has ever been made in the middle and upper reaches of the Valley itself. Scattered and fragmentary data dealing with the aquifers of the upper area exist, but the aquifers are not mapped and little is known about them.

Maps have been made of the piezometric surface of the principal artesian aquifer (which includes Eocene, Oligocene and lower Miocene rocks) but no maps have ever been prepared of the piezometric surface of the shallow artesian aquifers or of the water table. Thus, it is apparent that knowledge of the hydrology of the area is far from adequate.

Geologic studies in the field have been principally concerned with topography and the lithology of the surficial deposits, principally Pleistocene marine terrace sands. These studies indicate that a fluctuating sea level during the Pleistocene epoch is the agent principally responsible for the present topography, for at each long-time stand of the sea a shelving terrace floor was built out from the shore line. These terraces stand one below the other, shelf-like, and are generally separated by wave-cut scarps that are now represented by a change in slope of the land surface.

In the area of this report the shore lines of the several marine terraces are at approximately the following altitudes above mean sea level: 170, 100, 70, 42 and 25 feet. By far the largest part of the area covered in this report lies below the 70 foot shoreline.

In addition to affecting the topography the changing sea levels influenced the ground water by repeatedly flooding all or part of the area with ocean water. Remnants of the Pleistocene high level ocean waters, now diluted and altered by base-exchange processes, still exist in parts of the southern portion of the Kissimmee Valley and around Lake Okeechobee.

Close agreement is noted between the trace of the Pamlico and Talbot shore lines (25 feet and 40 feet above present sea level, respectively) and the inner boundary of the saline water in the principal artesian aquifer. This may be conincidence, but it also may identify the former zone of equilibrium (at depth in the aquifer) between fresh water on land and the salt water of the sea.

Data obtained from the drilling of test wells in the area of this report indicates that ground water below the bottom of the Lake, especially in the 40-50 foot interval below land surface, is not circulating but is stagnant. Most of this water is mineralized and more highly colored than Lake or swamp water, a good indication that fresh water is not moving appreciably through the sediments at those depths. The high color is taken from the enclosing materials which are deposits containing a considerable amount of black organic matter.

In attempting to collect water samples from the test wells it was noted that often the permeability of the sediments was so low that no sample could be obtained with equipment available. The part of the aquifer that is most important with respect to movement of ground water was found to be the upper few feet of the unconsolidated sand lying just below the land surface. Through this comparatively thin mantle of sand moves the water that flows underground into the Kissimmee River and Lake Okeechobee. The volume of water that thus finds its way into the Lake appears to be so small (approximately 2 acre feet per day) that it cannot account for the apparent difference previously noted in attempting to strike a hydrologic balance sheet for the lake.

CHAIRMAN VOLK:

Are there any questions?

MR. SCHRONTZ:

I want to call attention to something I have observed. There are a number of large lakes located along the Kissimmee river. They store, temporarily, a large amount of water and then gradually lose it. I think that is the reason a steady flow of water is shown on run-off hydrographs, as contrasted to the great variation in the rainfall. That, it seems to me, is a very important factor.

MR. FERGUSON:

Mr. Schrontz is entirely right. He has a background of study over the Kissimmee river basin that I cannot equal. It takes three and a half months from the time rain is deposited here until it reaches intermediate basins. The lakes in the valley therefore help ground retention. It takes ten months from the time rains fall in this general area until all the water from that storm would reach Lake Okeechobee.

MR. STEPHEN CHASE:

Tell me how much lower the water is now in the Kissimmee River than it was, say, sixty years ago.

MR. FERGUSON:

I wish we had records.

MR. CHASE:

I remember when I came here sixty years ago the water was up to the railroad

tracks. Kissimmee was a very little town. I have understood it was as much as sixty feet, forty feet, anyhow, lower than in those early days, before the canals were built.

Mr. Ferguson:

Along the shore line, that is very likely. Vertically, probably not so much. What you have reference to is a comparison of the water levels in the lake during very early natural conditions of the basin to those of the present. Undoubtedly your water levels were much higher before these canals were dug connecting the lakes. I do not have any records dating that far back. Only records and recollections of individuals like yourself.

Chairman Volk:

Dr. Gunter, would you like to say a few words regarding these two papers.

Dr. Herman Gunter:

I don't know that I can add much to what has been said. While we all know that well drilling is an expensive proposition, they have done an excellent piece of work in South Florida and it is money well spent.

To my way of thinking it simply means that we are going to have to do that same type of detailed work, not only in the Everglades area, but throughout the Kissimmee Valley area to be certain that we know what we are talking about.

Both Mr. Ferguson and Mr. Parker have given very good papers. They themselves know these papers are generalities, and that we can only speak largely in generalities at the present time. While this is quite true, we do know a great deal about our sub-surface conditions. We know that from well cuttings. We have gotten these samples largely through the wholehearted cooperation of a number of well drillers.

Through the years the Geological Survey has urged our well drillers to save cuttings from their operations throughout Florida, and it is from these cuttings that we have learned what we now know about sub-surface conditions in this area. Those well-cuttings may not always have been taken as we might have wished, but they have given us a general sub-surface picture we would entirely lack if we didn't have them to base our interpretation upon. In other words, we are indebted to the well drillers for much of the information we now have on our sub-surface formations for it is from the cuttings they have provided that we have learned the geological types and the thickness of those formations, as well as their age. I really want to pay a tribute to those in this field of work who have worked with us so faithfully through the years.

I would like also to urge this on each one here. Many are growers—vegetable growers or citrus growers, or packers and shippers. Wherever you have an interest in drilling artesian wells, don't let them go down and just drill you a well. Save the cuttings and submit them to the Florida Geological Survey or the U. S. Geological Survey, and we will study them and give you the permanent records of the characteristics and age of what you have drilled through. Thus, if your casing goes wrong, or something else happens to your well, we will be much more able to give you helpful advice.

Mr. Waldo E. Sexton:

If you are interested in wells in the Ft. Pierce and Vero Beach area there is a good man putting down wells in that section. He drilled me a well and charged $550 00 for it. It was put in so quick I scarcely knew it. He told me he went down as low as 900 feet in the Ft. Pierce area. So if you want to get a line on the geology of the Ft. Pierce and Vero Beach areas this man would help you, I am sure. He is a fine man to work with.

Chairman Volk:

We very greatly appreciate these excellent presentations on two very important aspects of our water conservation program, and are sorry indeed that Mr. Malcolm Pirnie of New York could not be with us to take part in the discussion from the standpoint of domestic water supply. We will now listen to a paper on the relationship of soils and soil type distribution to the problem under discussion.

SOILS OF THE KISSIMMEE VALLEY IN RELATION TO WATER CONSERVATION AND USE OF THE LAND

J. R. Henderson *

Detailed studies of the soils in the Kissimmee Valley have been made in only one county—Orange—and these were made almost 25 years ago. The information gained from these studies has been made obsolete by recent findings and. moreover. the report covering the work is out of print. However. some knowledge of the character and distribution of the soils of the area has been gained from reconnaissance surveys and miscellaneous observations made during the last decade.

This paper represents an attempt to summarize our present knowledge of the soils of this valley area, especially with regard to their moisture relationships and adapted uses. The relation between moisture conditions and land use is so close that a grouping of the soils on the basis of natural drainage immediately presents itself. For discussion, four soil groups are recognized. These are: (1) the excessively drained soils of the scrub ridge; (2) the well drained soils of the high pine land, high hammocks and blackjack ridges; (3) the imperfectly to poorly drained soils of the flatwoods, prairies and low hammocks; and (4) the poorly to very poorly drained soils of the ponds, swamps and marshes.

THE EXCESSIVELY DRAINED SOILS

This group includes St. Lucie fine sand and Lakewood fine sand both of which support a native growth of sand pines, scrub oak and scrub hickory. The St. Lucie soil consists of 2 to 4 inches of light gray to gray fine sand over white fine sand which extends to depths of 5 feet or more. The Lakewood soil differs from the St. Luicie soil mainly in having a bright yellow subsoil which usually is encountered at depths of 8 to 36 inches. The soils are so open and porous that they retain very little moisture for plant use and are not recommended for crop production of any kind. Fortunately, the total area of this kind of land in the valley is relatively small.

THE WELL DRAINED SOILS

Norfolk fine sand, Blanton fine sand and Orlando fine sand are the three members of this group. All of them are confined to well drained situations. Norfolk fine sand is the dominant soil of the high pine land and blackjack ridges. It consists of 4 to 6 inches of gray or brownish gray fine sand over yellow to pale yellow fine sand which rests on beds of sandy clay at depths of 4 or more feet. The depth at which the clayey material is encountered has considerable influence on the agricultural value of this soil, the shallow phases being considered more valuable than the deeper phases. Within the Kissimmee Valley, crops of this soil

* Soil Technologist, Soils Department, Agricultural Experiment Station, Gainesville.

are relatively less subject to cold hazards than on the others of the group and are widely planted to citrus, which is the only important crop for which it is used. During dry seasons, irrigation is necessary for best production.

Blanton fine sand is found mainly in the high pine land where it occupies slightly lower positions than the Norfolk fine sand. It consists of 4 to 6 inches of gray fine sand over pale yellow and light gray splotched fine sand. This soil is used mainly for the production of citrus. It is not as well protected against cold damage as is the Norfolk soil but does not require irrigation as early during dry periods.

Orlando fine sand is a dark colored soil found in the high hammocks and high pine land in the vicinity of Orlando. It consists of 10 to 12 inches of dark gray fine sand over pale yellow fine sand. It is considered to be the best well-drained soil in the area and is used for the production of truck crops as well as citrus. When used for citrus production the necessity for irrigation is not great but when used for vegetables irrigation is often necessary for good yields.

THE IMPERFECTLY TO POORLY DRAINED SOILS

This group includes Leon, Immokalee, and St. Johns fine sands which are extremely acid in reaction and have "hardpan" subsoils and the Sunniland and Palmdale fine sands which are neutral to alkaline in at least part of their profiles.

Leon fine sand is the dominant soil of the palmetto flatwoods and palmetto prairies. It is used for timber production and as range land. Some areas have been cleared and seeded to carpet and other permanent pasture grasses. As a general rule it is not used for cultivated crops because of the excessive costs of providing adequate water control, which includes both drainage and irrigation. This soil consists of about 4 inches of "salt and pepper" gray fine sand over light gray fine sand, which at depths of 12 to 30 inches rests on a dark brown to black so-called hardpan. This dark horizon consists of fine sand loosely to firmly cemented by colloidal organic matter.

The Immokalee fine sand is closely associated with the Leon fine sand which it resembles in many of its internal and external features. The dark brown hardpan, which is found at depths of 30 to 42 inches, is not as distinct as it is in the Leon soil. This soil seems to be a little better suited for native and improved pastures than is the Leon type.

St. Johns fine sand differs from the Leon soil in that it occupies slightly lower positions and has a dark gray to black surface. Because of the better surface soil this soil is better suited for improved pastures than is the Leon type. Shallow drainage ditches are necessary for removal of surplus water during rainy seasons.

Sunniland fine sand is found in the palmetto flatwoods of the lower part of the Valley. The vegetation includes a few scattered cabbage palmettos. The soil profile consists of 4 to 6 inches of gray fine sand underlain by light gray to light brownish-gray fine sand which at depths of 2 to 3 feet rests upon neutral to alkaline sandy loam to sandy clay. In other parts of the state this soil is drained and used for crop production but in the Kissimmee Valley it is used with the associated soils as

range land. Its value for improved pastures exceeds slightly that of the Leon and Immokalee soils.

Palmdale fine sand is a highly variable soil that is found in the small hammocks scattered through the flatwoods and prairies. The one outstanding characteristic of this soil is the presence of marl or other calcareous material in the lower part of the subsoil. With proper provision for water control this is a productive soil but the cost of clearing is excessive, especially for use as pasture land.

THE POORLY TO VERY POORLY DRAINED SOILS

This group includes Portsmouth and Plummer fine sands which are extremely acid and Delray, Pompano and Charlotte fine sands which are only slightly acid to neutral. They are all found in the wet grassy ponds and swamps. The Portsmouth and Delray soils are much alike except in reaction; they have dark gray to black surface soils 8 to 18 inches thick underlain by light gray fine sand. The Plummer and Pompano soils make up another pair which differ mainly in reaction. They have gray surfaces 6 to 8 inches thick underlain by light gray fine sand. Charlotte fine sand differs from Pompano fine sand in that the subsoil beginning at depths of 12 to 24 inches is bright yellow in color.

At present these soils are used in conjunction with the associated flatwoods as native range land. During dry seasons they provide good grazing while the grasses on the surrounding flatwoods soils are suffering for lack of moisture. These soils are all too poorly drained for crop or pasture use without artificial drainage. When drained, preference is given to the dark colored soils over the light colored ones and to less acid ones over similar extremely acid ones. For instance, Delray fine sand would be preferred to Portsmouth fine sand and Portsmouth fine sand to Plummer fine sand.

Several areas of peat are found in marshes bordering lakes. The total area is relatively small and little is known of the characteristics of these, their possibilities for reclamation and potential uses following reclamation.

SUMMARY AND CONCLUSIONS

The soils of the Kissimmee Valley have not been studied in detail but some knowledge of them has been gained from reconnaissance surveys and miscellaneous studies. On basis of our present knowledge the several soils of the area are divided into four groups according to natural drainage: (1) excessively drained soils; (2) well drained soils; (3) imperfectly to poorly drained soils and (4) poorly to very poorly drained soils. The present and potential uses of these soils are determined largely by the ease with which favorable soil moisture conditions may be established and maintained, keeping in mind at all times the effects water manipulation on one group of soils might have on the moisture conditions in each of the other groups and on the area as a whole.

It appears: (1) that the excessively drained soils cannot be used for the crop of the area without heavy irrigation; (2) that the well drained soils may be used for citrus production with only occasional irrigation; (3) that the imperfectly to poorly drained soils may be used as range land and for improved pasture with little attention to water removal and

(4) that the removal of water from areas of the poorly to very poorly drained soils would improve these soils but might have a detrimental effect on the surrounding soils and certainly would result in the wastage of considerable water that might be needed during dry seasons.

Chairman Volk:

Are there any questions?

Question:

Has any study been made of the movement of this water in the soil laterally instead of down?

Mr. Henderson:

I have no information on that. What do you think Mr. Ferguson?

Mr. Ferguson:

Only that we feel water enters the ground and moves laterally toward the nearest open or drainage channel.

Question:

I am speaking of grass ponds. Should we not keep those ponds, and avoid draining them? Do they not provide grass when the grass in other places is dying?

Mr. Ferguson:

Recen.ly there has been a tendency to drain these ponds. We certainly should not over-drain.

Question:

What part do those grass ponds play in surface drainage?

Mr. Ferguson:

I think the geologists will tell us the fact there is water in such ponds shows they have good "floor". In other words there is a bottom of some kind that keeps the water from moving downward and this probably explains why it remains a pond. There must be a very definite floor under these ponds if they are to serve any purpose as reservoirs.

Mr. Harold A. Scott:

The rate of flow laterally through the soil is only a few feet per 24 hours. That is to say the percolation horizontally is only very slow.

Chairman Volk:

I would like to call on Dr. Smith for any further discussion of Mr. Henderson's paper that he may care to offer.

Dr. F. B. Smith:

Mr. Henderson has very ably pointed out some of the most important problems relating to the conservation of water and the use of land in the Kissimmee Valley area. He told you of the general occurrence of soil types in the region. Among o.hers were the Norfolk, Blan.on, Leon, Orlando and St. Lucie series. Each of these soils have physical characteristics individual unto itself and each is different from any other. The Orlando fine sand, which is prized so highly for vegetable crops, was contrasted wi h St. Lucie sand which is rarely used at all. You might be in.ères.ed in the dis.ribution and extent of the development of these soil types.

Any drainage or water control program is go.ng to affect a large area. You are interested in knowing what is going to happen to your land. You want to know if it will be flooded or left high and dry. Or, if some one wishes to come into this area, he will want to know whether it is good Orlando soil or the St. Lucie sand he is cons.dering. A detailed soil survey would answer such questions. Unfortunately we do not have a detailed survey for any of the counties in this area, except for Polk and Lake; and only a small part of these counties are in this area.

The detailed soil survey shows the boundaries of the different soil types and the so.l survey report contains a description of the individual soil types, together wi h much practical information on management. It will not solve all of your problems but it gives a good foundation upon which to build a sound system of

agriculture. The soil survey is not expensive. It costs about 3 cents an acre and its value cannot be over estimated. It is of primary use to the Experiment Station as a basis for all soils investiga.ions and to the County Agent who interprets this information for the benefit of the farmer. However, it is of value to many other people as well. The man who owns land and is interested in its best use, the banker who loans money on land, the tax assessor, the homeseeker, public health service and highway engineers; all make use of the basic soil survey. There is no public service which cos s so little that is worth more than the soil survey.

Very little progress has been made in the soil survey of Florida to date. Lake and Polk counties are the only counties in the state which have been covered by a recent, detailed survey with published maps and reports. Alachua, Collier and Dade counties have been surveyed and reports have been written or are in progress. Manatee County is being surveyed. Parts of other counties in the Everglades Drainage District have been covered by a fairly detailed soil survey. This report is also in process of publication. We have only one man in the state surveying soils at present. This does not include the work of the Soil Conservation Service. They have several men doing farm surveys in different districts.

One of the greatest needs in your water conservation problem here in the Kissimmee Valley is a detailed soil survey to serve as a physical basis for planning. With only one man, it takes a long time to survey several counties. We greatly need added support for the development of the State Soil Survey.

Chairman Volk:

There is no question that it is difficult to do technical work of this type without the necessary manpower and funds.

The Importance of Water Supply and Control as Viewed by Certain Subject Matter Specialists

Chairman Volk:

We will now enter upon a planned discussion of the general water conservation problem in the Kissimmee Valley area from the standpoint of some of the more important subject matter angles. First, we will hear from Dr. R. A. Bair, Agronomist at the Everglades Experiment Station, who is very kindly substituting on very short notice for Prof. W. E. Stokes, head of the Agronomy Department and Vice President of the Society. Prof. Stokes was hospitalized only very shortly before these meetings began and greatly regrets his inability to be with us and taken an active part in these discussions, as do we all, I am sure.

THE AGRONOMIST

R. A. Bair:

I wish to add my regrets to those of Chairman Volk that Prof. Stokes is unable to be with us. He always very greatly enjoys taking an active part in such critically important discussions as we are undertaking today.

After looking over the assignments to the various other members of the panel to see what I could say that would not intrude too greatly upon their field of interest I have decided to say a few words regarding the importance of water and of water control from the standpoint of successful plant growth.

As you know, the plant leaves can get their nutrition in one way only, and that is in solution, so there must be sufficient water available to the plant in all of its stages of development for the leaves to get hold of the nutrients and fertilizers in the soil. The roots in order to absorb those nutrients and fertilizers, must have sufficient oxygen. They must have oxygen in greater or less amounts in the soil, so that if the water gets too high the plant literally starves to death because it cannot get the oxygen and nutrients it needs.

From this standpoint, the problem of the plant is to have adequate water—not too much, and not too little. From another angle, if the water table comes up too often and too high through salt or lime, as the case may be, amounts of these elements in the sub-strata may be brought to the surface in amounts that are harmful to the plant.

The next thing I want to emphasize is that most of our crop plants have been cultivated so long that they are extremely particular. They have been cultivated and selected for years in soils that have more or less ideal water conditions, and so their ability to tolerate extreme changes in water supply are not great, but rather limited.

In my work at the Everglades Experiment Station I am attempting to select grasses and small grains and strains of corn which will take what they have to take—and they have to stand a lot of water sometimes, as well as too little water at other times. It might prove out that if we had completely adequate water control we would be able to grow a good many varieties of small grains and grasses and some of the other crops that we cannot grow now, because they cannot stand the extremes of too much and too little water to which they are submitted.

Chairman Volk:

Thank you, Dr. Bair, for doing an excellent job of pinch hitting for Prof. Stokes on such short notice. We will now listen to Mr P. T. Williams, President of the Florida State Cattlemen's Association and prominent Ranchman in the Davenport area.

THE CATTLEMAN

P. T. Williams:

If there is any spot on earth a cowman should feel ill at ease, it would be in a place like this. I am not easily alarmed, but I am easily embarrassed. I have heard and read a lot about our water problem, but I never considered it to be serious.

I want to apologize to Dr. Allison for not having my subject prepared. I had planned to write a paper on water because everybody was talking about water, and I thought I should too. Then I was invited over to Tampa by Mr. Thomas. I had never heard of Mr. Thomas. I just saw his picture in the paper. I never took him seriously.

Well, we got over there and got started talking about water, and some of them pointed out that everybody knows all about it. We felt kind of ill at ease at that, as I don't know much about it. They took action the first thing. I thought maybe we had a political action committee.

Then they started talking about the cowboys, and I knew we were on trial. My friend, Doc. Keene whispered to me I had better plead guilty, but I said, no, I might have a surprise witness. Might be less water lost from our drainage district now than before. Anyway, they demanded that Governor Holland make a promise; and he promised to turn it over to Governor Caldwell. You know, the politicians could not get an answer out of these boys.

Finally, it landed in Mr. Mayo's lap. He called on Dr. Gunter, because he knew about it. I got uneasy because I didn't know whether I was going to have a drink when I got home or not.

I was really worried that night. So, when I got home, I rushed in and turned on the spigot; and it had some water. I also looked in Sears, Roebuck's catalog and they had a lot of pumps but no water; and my wife consulted Dorothy Dix, but she didn't have anything to offer. Finally, she said the Boy Scouts left some magazines on the porch. I found the *Engineering News*, and thumbed through that and found articles by several doctors. Since all the learned treatises said Florida will have an abundance of water always, I went to sleep and forgot about the subject of my present discussion until this very moment.

Chairman Volk:

Inasmuch as Dr. Camp is unable to be with us to discuss his particular phase of the subject we have asked Dr. F. E. Gardner, Head, U. S. Subtropical Fruit Field Station here in Orlando, to give us his views.

THE HORTICULTURIST

Dr. Gardner:

You have another pinch-hitter in the same fix as other pinch-hitters—nothing to say, and a few minutes to say it.

In fact, I don't know what I can say regarding the importance of water supply and control to plant growth which all plant men do not already know.

Every grower of plants realizes the importance of an adequate supply of water and also understands the necessity of avoiding too much water. He is also aware of the importance of control measures to avoid fluctuating groundwater tables which, during the periods of flood, rise and kill the roots of his plants and during the periods of drought recede and leave his plants high and dry. I do not propose to discuss the measures that might be taken to avoid such fluctuations.

However, I would like to say a few words regarding the need of the citrus tree for water. Its requirements over the period of a year, based on studies that have been made by the U. S. Department of Agriculture here in Orlando, vary considerably. In this connection I would like to refer to Mr. Ferguson's chart again. As Mr. Ferguson pointed out, more than half of our rainfall occurs during the four months of June, July, August and September. As to the water needs of a citrus tree, the transpiration of the plant over the period of a year follows very closely the rainfall curve, but with important differences.

Plotting the transpiration curve, it would follow along in some such fashion as I will quickly sketch for you. Thus, it may remain relatively high when our rainfall is relatively low; then drop off again during a period that corresponds to our high rainfall period. That means, of course, that during this latter period of the year we have excess water which is not required by the tree. It also means that in the spring months the requirements of the tree exceed the actual rainfall.

It is during those dry spring months that we are most apt to see evidences of drought in citrus trees. In fact, every year in some areas we suffer from drought in citrus groves. What happens to this excess water during this period?

I was impressed with Mr. Ferguson's remarks that 85 percent of the water which falls in the Kissimmee Valley is evaporated and that 15 percent runs off. I am surprised that 15 percent runs off.

We are fortunate in that respect, but if something could be done so we could use that 15 percent, particularly in the spring, it would be wonderful. It is a lot of water, and would go a long way.

Our problem of water control, the importance of it, is certainly emphasized by the character of our soil—being sand, and light in character, it holds relatively little moisture.

For example, our Norfolk soil has a water holding capacity of only about 3 or 3½ percent. That applies to the lower layer, excluding the upper surface soil, which has more organic matter, and may hold 6 or 7 percent. That is a small amount of water for the soil to retain, compared to a good loam, which may retain 17 to 20 per cent, or a clay soil, which may retain as much as 40 percent. This excess runs off and is not retained by our soil, as we all know. Everyone has observed how plants suffer for water during the period of the summer growth when rainfall is lacking for only a few days.

I keep thinking back to that 15 percent of the water which is lost and how useful it would be, if only it could be used. Even though we could not have it fall again on our plants in the form of rainfall, if it were stored in lakes or underground so it could be pumped out of wells, it certainly would be very much worthwhile.

Chairman Volk:

Thank you Dr. Gardner for your good help on such short notice. We will now listen to the views of Mr. H. C. Brown, veteran citrus grower of Clermont, on this general subject.

A CITRUS GROWER

H. C. Brown:

Every form of life depends for its existence upon a sufficient supply of moisture. This supply is furnished to Florida plant life from an average yearly rainfall of 56 inches. Unfortunately this rainfall is not measured out in daily doses, but a large part falls during a few weeks in the early summer months, as just pointed out by Dr. Gardner. Consequently the vegetation must depend for its support upon stored-up soil moisture or artificial irrigation. The 56 inches represents the total yearly water resource. In other words, that is the water deposit in the bank subject to being checked out during the year.

The fruit and vegetable crops are removed from the soil and largely shipped out of the State, carrying with them over two billion gallons of water from the water bank deposit. The production of these crops has consumed in transpiration over 25 inches of the rainfall. Much of this evaporation has also moved out of the State in the form of clouds.

The heaviest draft, however, against the water bank has been the run-off due to the failure of the soil to retain the rainfall and the opening up of water courses, the drainage of marshes, and the reckless waste of artesian wells running full capacity 24 hours each day, every day in the year.

The removal of the forests also has had a major influence on the failure of the soil to retain its moisture, and the increase in population is responsible for transfering much of the water supply.

The temperature is directly affected by the amount of water retained, and Florida's success or failure is measured directly by its climatic condition.

Mr. Williams is right. We do have plenty of water—in some instances at least. However, my feeling is that the citrus industry is of importance to everyone in Florida, since 38 percent of our agricultural revenue comes from this crop So, if the scarcity of water is affecting citrus, and it is being affected by something, as the soils of many of our groves, particularly on the high lands—and that is where the most of our groves are—are becoming what the "Crackers" used to call "greasy". They refuse to take water. It doesn't penetrate the soil as it did several years ago. We had about seven inches of rain a few weeks ago. I found that sometimes the rain didn't penetrate over a quarter or half inch. It just didn't go into the soil. As a result, our trees are suffering.

If our surface water is put under control and the levels of the lakes maintained at a safe elevation for the surrounding land for each 2 feet of extra surface water it is said a rise of 7 degrees in temperature can be realized. This will almost guarantee freedom from serious frost damage throughout central Florida. It would not take a great deal of money to raise the lakes two feet. If we can secure several degrees of additional warmth in winter through that means I will feel much easier. Lots of times a few degrees of temperature may mean the difference between success and failure.

One of these days, if we don't watch out, our bank account (water supply) will be very much over-drawn if we don't find some way to hold the water in the lakes.

Suggested Control Measures

Plug up the leaks by means of dams or fills thereby flooding marshes and swamps.

Increase the humus content of the soil and thus develop a greater water holding condition therein.

Use cover crops or other types of mulch in orange groves to retain moisture.

Control artesian wells.

Reforestation.

These and other means of water conservation and control must be seriously considered in order to prevent certain disaster to Florida citrus crops and the loss of hundreds of millions of dollars in tourist revenue as a result of a changing climate and failing water supply.

Chairman Volk:

Thank you Mr. Brown, even though your outlook is a bit on the dismal side. We will now listen to Mr. H. A. Bestor. Drainage Engineer, U. S. Sugar Corporation. Clewiston, who has had extensive experience in this field in that section of the State.

A DRAINAGE ENGINEER

H. A. Bestor:

I listened to Mr. Williams' discussion with considerable apprehension. He seemed to conclude that Florida will always have plenty of water. I would like to speak about the other side of the picture. There is an alarming loss of water. However, the really important thing is that we can do something about it, if we will.

One of Florida's greatest assets is in the development of the Okeechobee region, which practically has occurred within the recollection of all of us present. The area probably reflects the most rapid and important development of its kind in the country.

However, there is a wholesale waste of resources. Palm Beach County is the largest agricultural producing county in the United States. In the very few years I have been in Florida, I have seen most of that growth. That section of Florida is of enormous importance to the whole state. I would think that anybody who has faith in Florida and in the activity of Florida, is conscious that there is something there that should be taken care of. I was told when I was asked to make this speech that I was just to make a few remarks as a drainage engineer.

Much of the water we get down in the Everglades section originally falls in the upper part of the Kissimmee Valley. For a good many years everybody has been conscious of the fact that there has been a serious waste of water and that we should do something about it.

You know what has been done about it. I don't believe that the wasteful development which has taken place is commonly known; and what might happen in this upper valley, which, as most of you know, has been a source of trouble in recent years. We all know that there is much waste of our water resources. Things happen that we don't thoroughly understand. We do know something has happened and is happening which has changed things in the last twenty years. That means, with this continuing waste, and in this time of development in areas in which the state is trying to get rid of land, trying to get somebody on that land, has gotten to a point where you cannot do much unless you have a pretty thorough inspection of the situation. We must cut out the waste.

Now, practically everybody thinks, like Mr. Williams, that there is plenty of water. We have in South Florida an average precipitation of 50 to 60 inches. The bank or supply of water we have in here is largely our rainfall. That seems like a lot of water; and it is. But even with that amount of water, 70 percent of the time each year, Florida doesn't get a drop of water. Less than 30 percent of that water fails in the winter time. Something definite has to be done about conservation. In some way we must regulate the water supply. In some way we must fix it so the water can be made available and drawn on when needed. The principal problem lies in the fact that in Florida there is no individual or board to pass on the sufficiency of any plan that may be devised.

Florida is doing things in a big way. That is represented by the development of the sugar industry. People knew sugar cane could be raised, but I don't believe people know that the development of sugar production in Florida has made possible a yield of four tons of sugar per acre as compared to two tons in Cuba. Other products also can be raised under these conditions providing we have the proper control of water. Florida has an exceedingly vital interest in her water and cannot afford to waste it.

In the peatland area south of Lake Okeechobee, in my own experience there, through negligence as to handling of water, we have lost from 2½ to 3 feet of surface elevation. What can be done in the upper valley that discharges the run-off at the wrong time of year? What can be done to remedy that situation? There is something that must be done—something that must be given real consideration looking to the regulation of water. If we are not careful the crops you are growing now will be no more your citrus and your vegetable production in Florida. They will cease in the not too distant future, unless something definite and constructive is done. I will say that in 30 or 40 years the large-scale growing of vegetables in the Everglades area will cease if something is not done.

I have failed to see in 17 years in Florida any interest in or any planning around the fact that those waters can be controlled and that we can do something with them.

You used to dig a ditch. I have concluded that most of the organizations which came in to drain land had as their primary purpose to get the water off the land so the promoters could sell it and get out. If you could do something today and get your money tomorrow, that was all they were interested in.

Somebody must wake up and realize that the State of Florida has something of such value that we must plan how best to develop it and make permanent use of it. We must carefully consider what we are going to do, and when and how. We must make good and proper use of what nature has given us. There must be a broad, comprehensive plan.

In the area of sugar development on the south shore of Lake Okeechobee, there has been a certain amount of flood control work. The water has been held in the proper areas. You must not waste the water by draining it off into the sea. There must be long-range control of this most important asset. Why not run off the excess water which handicaps the use of the land and hold it back of dykes for future use? The necessity for planning is evident now in the soil conservation surveys that are being made in so many areas like the dust-bowl of the West. We have the same general type of problem. We are using the drainage ditches as a means to waste water. There are areas, however, in which there is regulation, where the water is drawn off and handled intelligently. In Florida, water cannot take care of itself. It has to be planned for and moved in such a way you can hold it in the degree that the characteristics of the land will permit for the best use of the land. If we let Tom, Dick and Harry take the water out today and destroy it, then tomorrow we will be sick.

Chairman Volk:

Thank you, Mr. Bestor. We are glad that, though you paint a rather dark picture for the future, like Mr. Brown, you also agree with him that something can be done about our water problems—and, in fact, must be done.

Inasmuch as Mr. L. T. Nieland, Forester in the Agricultural Extension Service, Gainesville, could not be here today to discuss his important angle of the whole program, I will now ask Mr. R. E. Norris, County Agricultural Agent, Lake County, Tavares, to say a few words on this subject.

A FORESTER

R. E. Norris:

I am considerably interested in the relation of water supply and control to the outlook for forestry in Florida but am not prepared to make any statement at this time.

Chairman Volk:

We will now listen to the views of one who has had much experience with the agriculture of this State and of this County of Orange, Mr. K. C. Moore, County Agricultural Agent with offices here in Orlando.

A COUNTY AGRICULTURAL AGENT

K. C. Moore:

The yearly average amount of water falling from the clouds on Central Florida is a little over 51 inches. This is from Weather Bureau records of 14 stations within a radius of 100 miles from where we are sitting. For Orlando the average annual precipitation is 52.31 inches. What becomes of it?

According to the chart which Mr. Ferguson presented earlier this morning about 42 inches of water is evaporated from the free water surfaces of our lakes and streams. The other 10 inches of water which falls on these areas either runs off or seeps into the underground reservoir. When all of the lake areas are considered this amounts to quite a lot of water. Records kept for 5 years in California showed that 72 inches of water evaporated from the surface of open black pans.

When our cultivated soils are exposed to the sun's heat extremely rapid evaporation occurs. Some records kept by Mr. George Bahrt have shown a temperature of 130° F. at a depth of 3 inches in cultivated soil on a summer day. This is hot enough to quickly dry out the surface soil, and to evaporate what little capillary moisture rises into this zone.

Mr. G. M. Volk estimates that about 15 percent of the moisture falling on cultivated surfaces at Gainesville evaporates and approximately 50 percent percolates through the soil that he was dealing with. In some of the looser higher soils it is likely that more than this amount percolates through.

The shade of cover crops prevents some surface evaporation but this is negligible as compared to the amount of water used and transpired by the plants themselves.

I was surprised by some figures on the amount of water transpired by a field of cabbage, which I recently looked up in an old college textbook on Botany by Dr. George F. Atkinson of Cornell. He stated that in a 4-months season approximately 17 acre inches of water were transpired by the cabbage plants growing on the land.

These figures seem mighty high. Three such crops a year would account for our average rainfall of 51 inches. Two such crops and a heavy summer cover crop would use and transpire about as much water as falls on the land.

But some of the rain falling on the vegetable fields seeps away or is drained away—so we have to irrigate. One of our large vegetable farm operators recently stated in a letter to me that:

"I am of the opinion we do have more irrigating to do in proportion than 15 or 20 years ago. This is partly due to lowered water tables and also the rapidity with which the land dries out."

In USDA Bulletin No. 1876, entitled "Irrigation Problems in Citrus Orchards," reports of 5 year records, kept in California, show that mature citrus trees (20 to 30 years old) transpired 24 inches of water per year. In other words an acre of these trees used 24 acre-inches of water per year. Our citrus trees in Florida of similar size will use and transpire this much water or more, because there is plenty of water in our soils during our months of highest temperatures, whereas, in California, the rains fall during the months of low temperatures.

There must be a tremendous loss of water by percolation through our porous sandy soils. There is nothing much to slow this down. How much is lost in this way or where it goes are questions that our hydraulic engineers and geologists will have to answer.

During the season of clean cultivation there is some evaporation. We are lucky to have our cover crops grow when water is abundant, since the water transpired by them would possibly seep away anyhow.

The above bulletin also reports that the group of groves averaging the highest yields received about 25 acre inches of water by irrigation during their dry season, which is the summer. Some made a good yield with much less water applied, but the highest average was from those receiving at least 25 acre inches of irrigation water.

Most of our grove irrigation here in this section of the state is done in the late fall, winter and early spring. Every year more groves in Orange County are being irrigated, and more water is being required for this purpose.

When I came to this county 18 years ago, groves with irrigation equipment were few and far between. They were curiosities many would drive miles to see. The pumps delivered 100 to 300 gallons of water per minute.

Production managers have reported to me that they were applying from 5 to 9 acre inches of water a year previous to the past 3 seasons. Seasonal rains during

these recent years have generally been better and labor has been in shorter supply. As the trees grow larger more water will be needed.

Based on our County A.C.A. records, we conservatively estimate that 13,000 acres of groves in Orange County are now equipped for irrigation. During this past year 25 deep wells were sunk in this county.

While our Citrus growers are boring wells for a source of water some of our cattlemen are sinking them as a drainage outlet. Some of the best pasture soils need drainage. In fact there have been several hundred miles of shallow surface ditches opened on our cattle ranches and dairy farms this year.

These are some of this County Agent's reasons for urging that this group give its full influence to working out some well-formulated plan for water control and conservation, not only in the Kissimmee area but for the state as a whole.

Chairman Volk:

Thank you very much, Mr. Moore. It is quite apparent that in your diversified field of Jack of All Trades and Master of many of them that you have in some way found time to give very good and serious thought to this problem of water conservation and control. We are indeed glad to have your comments as a part of the record. We will now listen to the remarks of a mechanical and hydraulic engineer, Mr. Roy O. Couch of Grant, Florida. Mr. Couch has extensively pioneered the handling of water over low lifts such as are the common need in Florida and particularly in the Everglades area where his first work was done. Mr. Couch is also an electrical engineer of very considerable ability.

A MECHANICAL AND HYDRAULIC ENGINEER

R. O. Couch:

A proposed system of water control that will conserve the rainfall by preventing too rapid run off; that will assure adequate municipal water supply without any danger of contamination by salt water infiltration; that will increase the temperature during cold weather; that will prevent the destruction of peat-muck lands by fire; that will preserve the lands not under cultivation from subsidence and oxidation; that will preserve and increase the fish and wildlife; that will allow a proper water table to be maintained on any given area of land being cultivated is something that is badly needed in Florida and well worth looking forward to.

All of the above could be accomplished by restoring overdrained areas, as near as possible, to their original condition. This could be done by placing control gates or locks in existing canals and raising the water level so as to flood the land when not in use. At present there is only a small percentage of the lands in most drainage districts that is in actual cultivation, and under this proposed plan the lands under actual cultivation would be provided with surrounding dikes, with a complete lateral and field ditch system. With the area enclosed by the dikes, water would be removed from such areas by efficient two way pumps. Water also could be admitted through the pumping unit if irrigation was required, and in this way an exact water table maintained that would be best suited for the crop being produced. The surrounding flooded area would provide a considerable protection from cold weather. To secure such protection some percentage of these lands should be set aside for flooding.

In developing new areas it would not be necessary to cut deep and expensive drainage canals as the natural slope and drainage direction could be ascertained then dikes could be constructed so as to form a channel on the surface of the land directing the flow of water along its natural course. The dikes could be spaced any desired distance apart, thus a canal 1,000 feet wide would cost no more to build than one of a 100 foot width. This surface canal could be so constructed that it would be the proper area to provide an ample water supply and suitable frost protection. Lateral channels of the same type could be built to complete a comprehensive water control system.

Water control on areas within this drainage system would be accomplished on tracts under cultivation as outlined above. During such times as the cultivated areas were not producing crops, water could be admitted to flood the land, destroying all insects and benefiting the land in many ways.

On some lands underlaid with very porous limestone the seepage factor might be so high that this plan would not be feasible. Actual operations in the Everglades section of Florida have been very successful. Thus the Richland Drainage District has about 3,000 acres of land near Pahokee. The surface of this land is about four

feet below the average level of Lake Okeechobee. Water control is taken care of by two 40,000 G.P.M. two way pumps—they have been very successful and have had no difficulty in maintaining a proper water table. Numerous other tracts of land near Lake Okeechobee are being cultivated, the water control being almost the same as outlined in this proposed plan. Though these lands have surface levels below the surrounding water, yet, they have no difficulty in maintaining an exact water table.

The lands in the St. Johns and Kissimmee River Valleys would be ideal for development under this proposed water control plan. No doubt there are other large tracts of land within the state that could be handled in a similar manner.

CHAIRMAN VOLK:

I would like particularly to emphasize that if we could distribute our water over a longer period we could have very effective utilization and leaching would not be nearly as serious as at present. When we get a cloud-burst, it takes 6 or 7 inches of rain to saturate four feet of soil. After that 7-inch rainfall last fall and full saturation of the soil had developed practically every drop of water that fell after that was lost. If we could re-distribute our rainfall to provide such advantages it would be marvelous. Since we can't we must work towards the same general ends with the means at hand.

I would now like to ask Mr. Warren Roberts, long-time Editor of the *Orlando Sentinel* and staunch proponent at all times of water conservation and control to say a few words.

AN EDITOR

WARREN ROBERTS:

When I first came to Florida five years ago one of the first friends I made was Mr. P. E. Williams whom you heard make a very witty address just now. Although we don't see each other very often, I believe Mr. Williams will agree with me that our friendship had grown during those years. So I want to tell you something about this man Williams.

In the first place, if ever a responsible landowner could afford to forget water problems and go to sleep, that man is P. E. Williams. On his twenty square miles or so of valley land, most of which is muck, he has established the kind of water control we want in Florida.

His land was originally under water. However, he established a canal there, not only to remove water, but to act as a reservoir on which he can draw to water his pastures when he needs to do so.

If you want to see a good example of water control, Mr. Williams can show you that type of control for his peculiar kind of problems. If I owned the land I would surely invite you down there.

At heart Mr. Williams is a conservative. I sat with him and Mr. Ellis Davis, and a number of other eminent gentlemen on a committee known as the Kissimmee Valley Flood Control Committee. I merely bring that out to show you why Mr. Williams went to sleep so easily. He has his proposition under control. He doesn't need to worry. He is right in saying there is enough water. For he gets his 53 inches, and he utilizes it, and it is enough for his particular purpose and situation; and the Lord will continue to send it, so he has no problem. However, some of the rest of us do have problems and that is what we are gathered here to consider. And I believe that something worthwhile is going to come out of all of this discussion. However, my main purpose in rising here was to set you right on Mr. Williams.

CHAIRMAN VOLK:

Thank you Mr. Roberts for your constructive remarks. I have just received a wire from Mr. Frank Holland advising that it will be impossible for him to be with us this afternoon but he plans to attend this evening, when he will speak on the proposition of a Statewide approach to the solution of our water problems.

If there are no further suggestions or comments the discussion is closed until 1:30 P.M.

SYMPOSIUM: AN APPROACH TO A SOLUTION OF THE WATER CONSERVATION AND FLOOD CONTROL PROBLEMS OF THE KISSIMMEE VALLEY

1:30 P.M.—December 7

Editor Warren Roberts, Orlando Sentinel, Presiding

CHAIRMAN ROBERTS:

Gentlemen, you know we have two serious shortages in Florida, one affects some people very personally, and the other, generally. I speak of the water shortage and liquor shortage. Congress is looking into the liquor shortage because they are more deeply affected by that than they are by the water shortage, but we are particularly concerned over the possibility of being without as much water as we need some time in the future, and so I think it is the part of intelligence to do something about it before that happens.

You know we are peculiarly blessed in Florida in our present political situation as far as the State is concerned. We have an out-going governor who has shown his interest in the affairs of the State, and particularly in this problem we are discussing today. He has pledged his cooperation, not only during the remainder of his term, but also, he says, as long thereafter as we desire to call upon him; and I think that is a pretty important omen for what we are trying to do.

We are fortunate in that the present governor and the governor-elect can sit together around the table and talk over affairs of State, and let their policies overlap each other, or, rather, that we can pass from one administration to another without the usual jog which occurs, and so the other day Governor Holland and Governor-Elect Caldwell sat talking over this very subject.

I do not need to introduce our first speaker to you, because you know him. In fact, you know him so well that you recently chose him to be your next governor. I will now ask the Honorable Millard F. Caldwell to address you and give you the viewpoint of an administrator. Governor Caldwell.

GOVERNOR-ELECT CALDWELL:

Thank you, Mr. Chairman. This will be one of the best speeches made here today, because the shortest. If there is anything I know nothing about, it is this question of water control. I am gradually coming to the conclusion that I am not by myself in this category.

I would like to leave this thought with you, and that is that Florida will either grow and develop, or take the opposite course, depending, to a great degree, upon the proper conservation of water.

They tell about Senator Walter Rose riding up the street with some visitors, when, as they passed a 68-story building, they asked him what it was, Walter said: "I don't know. Hell, it wasn't there yesterday." You won't get your problems serviced quite that fast!

I take it for granted that any and every person in this room knows you are dealing with one of the most vital, if not romantic, problems in this State.

If, in your combined judgment, you can reach a course of action which is sound and workable, which will be, at the same time, a course of action that will bring some of the Federal money to bear on the Florida situation, there is no reason why the Conservation group in the government, and the army engineers, and any other related interests cannot interest themselves, not only politically, but financially, with control and water conservation getting a great deal of attention in Washington.

We have one of the hardest nuts to crack, right in this State. It must be solved in a way not to unduly penalize any of the individuals in the State or community. It is a broad problem, but it can be made a practical problem, and one that can be solved, a step at a time.

All we have done the last few years is just to talk about it. I think the time has come when a concrete proposal should be placed before the Legislature that

will set up an Authority which can take the problem and work it out—one step at a time. There are some things which can properly be done. They ought to be done. A number of other problems are in an uncertain stage. We do not have the answers to them, but as a solution is found in each case, it should be accomplished. In this way, probably in the course of 15 or 20 or 30 years, you will reach a fair solution of the broad over-all problem.

This is your problem here. It is of no more interest to me than it is to you—no more interest to the Legislature than it is to you.

The State does not have the facilities, and the Legislature does not have the time to evolve the entire problem. If you can do it, and organize it in a way that will appeal to the members of the Legislature, not only from the Everglades, but from West Florida and North Florida, I think you can get it by, but it must be a real and thorough study. Get out the engineers. Make it common sense. We stand ready to go all the way with you on this task but you must work it into presentable form first. Thank you so much.

CHAIRMAN ROBERTS:

I think we do not need any further inspiration to work out the problem. If our incoming governor is willing to go along with us, it means success—a great measure of success during the period of his administration.

I know the law-makers are interested. We have two or three here today—Tyn. Cobb, Senator Rose, Senator Carroll, and maybe some others, already committed to the general idea that they must save the situation for us; and with the governor as our leader, I am sure we can go where we want to go and should go; and indeed where we must go.

We expected to have Col. A. B. Jones, District Engineer, Jacksonville, with us this afternoon, but he was unable to come. However, he sent an able alternate in Mr. Harold A. Scott of his department.

INVESTIGATIONS PERTAINING TO WATER CONSERVATION AND FLOOD CONTROL IN THE KISSIMMEE VALLEY

Col. A. B. Jones *

The first U. S. Engineer Office in Florida was established at Key West during February 1845. This office was almost exclusively concerned with construction of fortifications at Fort Taylor reservation. It wasn't until about 1852 that the U. S. Engineers began river and harbor work in Florida. The first appropriation for river and harbor work consisted of $10,000 for a general survey of the St. Johns River, resulting in a map which was published in 1856. About 1889 private interests constructed the first canals in the Kissimmee River Valley, connecting the various lakes to make navigation possible from Lake Tohopekaliga to Lake Okeechobee and thence to Fort Myers. From then up to the present time a few small improvements have been made and a small amount of maintenance has been completed. In 1930 the first appropriation was made for flood control studies. The reports authorized and prepared at that time are now known as the 308 reports and include studies for power, flood control, irrigation and navigation.

At the present time there are two reports authorized by Congress. One is a navigation report and the other is a flood control report. The navigation report provides for investigation of the feasibility of a waterway from the St. Johns River to the Kissimmee River, in Florida, and thence to the Okeechobee Cross-Florida Channel. This report was authorized by the River and Harbor Act 30 August 1935 calling for a preliminary examination. The flood control report provides for investigation of the feasibility of flood control works throughout the St. Johns and Kissimmee River valleys. This report is known as Indian River and Upper St. Johns River and Marsh, North Fork of St. Lucie River, and Kissimee River and their tributaries, and was authorized by Flood Control Acts approved in 1937, 1939 and 1941. The flood control authorization of 1941 is a combination and expansion of the previous flood control authorizations. It can be seen from the title that the scope of this report covers flood control for most of Central Florida.

In the river and harbor act before Congress this week in Washington, there are two navigation items for this area. The first one is for consideration of navigation of the Kissimmee River. The second is for a system of interlocking open rivers and canalized channels for a depth of 12 feet and of suitable width to be constructed through rivers and lakes and by land cuts as follows: From Palatka, Fla., to the Indian River at Sebastian, Melbourne, Eau Gallie, Cocoa, or such other locality as may be found most suitable; from Titusville westerly to the St. Johns River, thence to Lake Tohopekaliga; from Lake Tohopekaliga to Leesburg, on Lake Harris; from Lake Harris to the St. Johns River near

* District Engineer, Office U. S. Engineers, Jacksonville. Delivered by Harold A. Scott, Civil and Hydraulic Engineer, Office U. S. Engineers, Jacksonville.

Dexter Lake or alternately from Lake Harris to the Wekiwa River, thence to the St. Johns River; and from Lake Tohopekaliga via the Kissimmee River and Lake Okeechobee to a connection with the Okeechobee Cross-Florida Channel.

All work has been stopped on the authorized reports for the duration of the war to conserve manpower, by order of the President in 1942.

Before discussing the status and scope of the flood control report of the Indian River, Upper St. Johns River and Marsh and North Fork of St. Lucie River, Kissimmee River and their tributaries which we are all interested in today, I would like to describe the procedure necessary to obtain any river or harbor or flood control, or combination improvement by the Government.

A project for improvement is not initiated by the Government, but by the people of the locality. Among those who would be interested and likely to take the initiative are shippers of all kinds, merchants, manufacturers, owners of water front property, owners of property subject to flooding, and all those citizens interested in provision of navigation and flood control and the development and growth of the vicinity. Recognition of a need may arise, not only in connection with a new project, but also whenever a project, although completed under the limitations previously considered adequate, requires expanding in some or all particulars.

The first step is to obtain the authority for a preliminary examination by the Army Engineer Corps. Those persons who are interested request their representatives in Congress to introduce a bill or resolution authorizing a preliminary examination and survey of the proposed project.

The project is presented to Congress, usually appearing in a list of similar projects as a part of the regular River and Harbors or Flood Control Bill; it may, however, be acted upon by means of a special bill. As soon as the bill containing the project becomes law, the project is approved for preliminary examination and survey.

The preliminary investigation is assigned by the Chief of Engineers to the District Engineer stationed in the locality, Jacksonville, Fla., in this instance. A public hearing is then conducted, at which the District Engineer invites a full discussion by all persons who are affected by the project. At the hearing benefits are pointed out or objections may be raised, and the public has an opportunity to bring forth all of the various considerations involved.

Aided by this information, the District Engineer submits a report through the Division Engineer to the Chief of Engineers. The report is referred to the Board of Engineers for Rivers and Harbors for review and recommendation. If the Board's action is favorable, the District Engineer is authorized to make a detailed survey report. The survey report includes definite design plans and specifications and estimates for the project. It is then submitted through the Division Engineer to the Chief of Engineers and the Board for recommendation to Congress. Upon approval by Congress and the President, the project is authorized by law. A separate appropriation bill then provides funds for construction of the project.

The status and scope of the Flood Control report, Indian River, Upper St. Johns River and Marsh, North Fork of St. Lucie River, Kissimmee River and all their tributaries, which we are particularly interested in

today, covers an area that has possibly greater potentialities than any other area in Florida.

The upper St. Johns River basin is considered to be that area from the source of the river in the broad, flat marshes, to a point somewhat downstream from Lake Monroe. The basin is a wide, flat, grassy prairie through which the stream meanders in an extremely tortuous course. Several large and beautiful lakes are scattered along the valley. The river banks in this upper section are in general only about a foot above low water stage. The river bed is below mean sea level as far upstream as Cheney Highway (State Road No. 22). The greatest concentration of all of the entire river lies between Lake Poinset and Puzzle Lake, amounting to over 10 feet in 30 miles. The drainage area above Cheney Highway consists of about 1300 square miles. Thousands of acres of rich pasture and farm land are under water for six to nine months during a wet year such as occurred in 1941. Relief could be brought to these flooded areas by proper water control.

The Kissimmee River has its source in several small streams which rise just south and west of the City of Orlando. These small streams, flowing in a southerly direction, empty into East Tohopekaliga, Tohopekaliga, Kissimmee, Cypress and Hatchinaha Lakes. Actually, Kissimmee River proper begins at the outlet of Lake Kissimmee. It is approximately 56 miles by river from Lake Kissimmee to Lake Okeechobee. The Kissimmee watershed extends about 95 miles north and south, and 40 miles east and west at its widest section. The drainage area of the Kissimmee River is 3,260 square miles near Okeechobee, Fla., and 1,850 square miles at the outlet of Lake Kissimmee. There are huge areas in this valley which are subject to flooding during the rainy season. Although much has been done by private interests to provide drainage canals to carry off the excess water, relatively little has been accomplished in controlling and conserving the natural water supply.

At the present time practically all topographic surveys have been completed in both the St. Johns and Kissimmee River valleys. Although the work on the report has been stopped, stream flow measurements have been continued in cooperation with the U. S. Geological Survey, especially in the upper valleys where no data existed, so that this data would be available when once again we resume study of the report.

The economic survey is approximately 50 percent completed. During 1941 the U. S. Engineer Office spent considerable time having its representatives visit the residents of the Kissimmee and St. Johns valleys to determine the economic benefits which would be expected by provision of certain flood control works. This survey was supplemented shortly thereafter by Mr. Cudell, who was loaned to a local group of ranchers and business men by the Governor of Florida to carry on this study. All the data collected in these two separate studies are on file in our office for investigation when study of the report is resumed.

Preliminary plans fostered during the initial studies for the St. Johns River valley readily recognized that relief from floodwaters could not be obtained by discharge down the St. Johns River valley alone. This can be understood better when it is realized that the river bottom at Cheney Highway is below mean sea level and the mouth of the St. Johns River is approximately 220 miles away. This means that for the water to leave the valley it must build up its own slope or head to create flow. Mean-

while, 4 to 5 miles directly east lies Indian River, a tidal lagoon. There is a fall of a few feet at Cheney Highway up to possibly 25 feet near Fellsmere between the two rivers. Therefore, one proposed plan of relief is to provide channels with proper control works such as weirs and gates at several strategic locations in the upper St. Johns River valley. These channels would extend from the St. Johns River directly east and empty into Indian River. The operation of the control works would be along these lines. First, during the rainy season when a surplus of water existed and there was danger of flooding the pasture lands or areas beyond the marsh limit, the excess water would be drawn off and discharged into Indian River and thence into the ocean. Second, at the end of the rainy season the marshes would be allowed to fill up so as to be as full as possible during the winter season to eliminate drought and provide frost protection for the orange groves and agricultural interests throughout the area. It is not intended to drain the entire area known as the St. Johns River marshes and dry up the upper St. Johns River, as it is believed that this would be contrary to the desires of local interests and defeat the purpose of water control and conservation.

In the Kissimmee River valley one proposed plan provides for improving the existing canals and providing suitable control works at the lake outlets. During the rainy season the excess water would be discharged down the Kissimmee River and the lakes maintained at a reasonable elevation. Here again toward the end of the rainy season the lakes would be allowed to increase their stages so as to end the season with lakes full, thereby offering a maximum of drought and frost protection to the varied interests in the valley. It is not intended to drain the valley but rather to regulate and conserve the natural waters.

Consideration has been given to several other plans to control and conserve the excess water but it is still too early to determine which plan will be recommended.

As stated before, work upon the Indian River, Upper St. Johns River and Marsh, North Fork of St. Lucie River, and Kissimmee River and their tributaries report has been suspended since 1942 by order of the President for conservation of manpower during war time. To resume studies on the report it must be shown by local interests at this time that completion of the report would be of immense benefit and eventually contribute to the war effort.

It should be reemphasized at this time that authorization of this report by Congress or authorization of any preliminary report of any proposed project for navigation or flood control or multiple purpose project does not in itself authorize the construction or carrying out of the project. The construction of a project must first be authorized by Congress, which bases its decision almost entirely upon the District Engineer's report which is in great part influenced by information furnished by local interests. Attention is invited to the fact that provision of a navigation or flood control improvement by the Government must be economically justified. First it must be shown by local interests that a demand and use exists which would result in great savings of shipping costs by provision of a navigation improvement or that protection from loss of life and property damage by provision of a flood control improvement along with other benefits are sufficient to economically justify the improvement.

It must be shown that the annual benefits which would accrue due to provision of a navigation or flood control improvement would be equal to or greater than the annual charges including maintenance, interest, amortization and any other incidental charges of the improvement. If this cannot be definitely shown by local interests and incorporated into the report by the District Engineer the recommendation for the project will be unfavorable. If, however, it is shown that the annual benefits including contributions by local interests exceed annual costs, including other charges, then the project will receive a favorable recommendation.

It behooves the sponsors of a project, therefore, to substantiate the claims made regarding the benefits expected to be derived from the project and furnish all information and assistance, including the amount of local participation and availability of rights-of-way to the District Engineer so that complete information may be presented in the report to Congress.

I would like to mention at this time the necessity for combining the efforts of all interested parties, local, State, and Federal, so that the final improvements will benefit all and not a few. I say this because several instances have been brought to my attention where one or two people have attempted to improve their own holdings by instigating minor water control works. In these instances, while benefiting the originator, they have caused ill feelings and hardships upon adjacent property owners. Therefore, if we are to avoid this, we must all join together and combine our efforts to work toward a plan which will develop the natural resources and improve water control and conservation in these two great valleys and provide benefits to all of the people.

Chairman Roberts:

Thank you Mr. Scott for your very clear and forthright discussion of the very heart of our problem. As far as I am concerned there is no muzzle on this meeting. If you wish to ask Mr. Scott any questions, it will be in order. I think he has shown you that it is the purpose to harmonize all these water interests so that instead of being conflicting interests they will be coordinated and cooperating interests.

It has been said that the interests of the cattle growers and the citrus men are, in a measure, opposing. I cannot see how that is so at all. What we want is a complete utilization of our water as far as we have need for it and it is available.

I have talked to many cattlemen and found no opposition on their part, and certainly there is nothing they can do in the lower valley that will hurt the ridge country.

Mr. Scott:

I would like to say, in addition, that in my studies of flood control in connection with the War Department the most important problem we are faced with is educating the ranchers and farmers and citrus growers with what we want to do, and the definition of water control. I have talked to ranchers who would just as soon throw me out when I mentioned drainage, and when I speak of water control, they are for me 100 percent. As soon as you can prove to them that you are trying to benefit them, to hold water back for them when they need it, and get rid of it when they don't, they are for you 100 percent.

Everyone you meet, as you leave, if you'll talk to them along the line of water control, and spread the word throughout the two valleys, it would be of great assistance to the U. S. Engineers, the State workers, local business men, and all others, in fostering a better water control program.

Question:

Did I understand you to say that water in the valley didn't affect the hills?

Mr. Scott:

Yes. What I meant was, if we start with water in the high country, it will be gradually released for the lower valley, and they can't do anything in the lower valley to handle the problem. That's very important. I want to emphasize that just as strongly as possible. There must be conservation in the hills. What is done in the bottom of the valley will not affect the man on the hill. We need to get that over very definitely. Then we can begin to get together more effectively.

Potential Contributions by Other State and Federal Agencies

Chairman Roberts:

We now enter upon a series of discussions by representatives of several State and Federal agencies in relation to the potential contribution of each to the solution of the problem in hand. Our next speaker is a man who has done more than any other to save the State from catastrophe. Time was when there was a lot of discussion about whether or not there should be a sea-level canal across Central Florida, and would it jeopardize the fresh water situation in this part of Florida, and South. And our State Geologist said to me: "We have no guarantee that it would not," and since that time the sea-level canal has been abandoned, and they have suggested a barge canal with locks, to which I have heard no serious opposition.

I want to introduce this next speaker as a man who is a real friend of the proposition we are discussing here today—our State Geologist and Director of the organization for which he will speak, Dr. Herman Gunter.

FLORIDA STATE GEOLOGICAL SURVEY

Dr. Gunter:

I didn't know the canal was going to be mentioned, or I might have been conspicuous by my absence. However, I do appreciate Mr. Robert's kind remarks.

To my mind, conservation or control, simply means proper utilization. If we boil it down to that, I think we will all be very happy to undertake the suggestions made by Colonel Jones in the last paragraph of his address so ably presented by Mr. Scott.

I agree that we should cooperate and coordinate our efforts—all of us, and then go in with a unified front, and try to have something done at the next Legislature. The cattleman's interest is the grower's interest, and the growers interest is the cattleman's interest, but until we can all unify our efforts and go in with a combined, fully coordinated report, we are going to have a much more difficult time, as I see it, to get our work done, than we would otherwise have. I believe that failure to definitely coordinate our efforts is going to be a real stumbling block for us in the accomplishment of what could otherwise be done quite easily and effectively.

As Mr. Roberts has said, the State Geological Survey has been interested in this problem of water supply ever since it was established in 1907. Even prior to Dr. Seller's appointment as the first State Geologist there was much interest in it. Certainly he was interested in this very problem, even prior to his appointment, during the time he was connected with the University of Florida as shown in Bulletin 89, which deals with the underground water supply for farms.

During the intervening years, the Florida Survey, as best it could, has endeavored to keep a clear record of many facts relating to our ground water supply. Not that we do not appreciate our surface water supplies, but that we do appreciate, the more, the problems of our ground water supply, and did so even in that early day.

Thus we have mostly been concerned with our ground waters. I might say also that in no other state in the union, as far as I know, are the relationships between ground and surface waters more close than they are right here in Florida. Some of our springs are ground water springs though some of them are mostly surface water and would come under different agencies. While we have our differing responsibilities that does not need to mean that we cannot correlate these relationships.

I think I might briefly mention this—that during the years, the Florida Survey has cooperated, especially during the years 1930 to the present time with the U. S. Geological Survey in trying to get some of the answers to some of the problems that we were almost certain would develop. During these years we have kept records

of wells in certain critical areas, and those records are now available and have served us in good stead.

More recently, we have spent some of our limited funds in cooperation with the Surface Water Division of the U. S. Geological Survey. In this way we have helped that agency in getting the records of our streams and some of our rivers.

In order that we may more effectively undertake these investigations, we are now asking for an increased appropriation at the coming session of the Legislature. In fact, it seems like a big figure since we are asking for three times as much as we have been receiving, namely $15,000 for ground water investigations and $4,000 for surface water investigations.

If we receive that amount of appropriation the government will match it with a like amount through the U. S. Geological Survey with whom we are cooperating very closely in all of this work. We feel that we can effectively and efficiently and intelligently spend those funds for the prosecution of this very important work. While the above may seem like a small sum, we don't want any hysterical appropriations. As a matter of fact excessive appropriations would not help us. We cannot quickly get efficient, well-trained help in these particular lines of work. However, by having these conservative appropriations, I believe we can spend those funds intelligently; and if I know my associates and co-workers as well as I should, I believe we can get along quite well with this comparatively small amount of help.

Our first water supply bulletin dealing with a little area in Central Florida has long been out of print. However, the data it contains is still utilized in our 34th and 35th reports dealing with ground water conditions of various parts of Florida, and in current bulletin No. 27 which deals with the ground water situation in Central Florida. This latter bulletin was gotten out in cooperation with the U. S. Geological Survey, and contains results concurrently obtained.

Orlando has long used a drainage well for disposal of storm water and sewage. That has brought on serious problems that have not been anticipated. We have recognized the situation for some time and have kept records of wells in this area for a number of years. They have problems in the Sarasota region, too. One of our reports deals with that area.

Then in northeastern Florida, in the Jacksonville area, Mr. Cooper of the Ground Water Branch of the survey has recently gotten out a report on the two northeastern counties represented. Industrially, that area has brought on problems we did not fully anticipate and which were not present a few years ago. Some of those mills use as much water each day as the city of Jacksonville. The same thing is true in the Panama City area. We haven't a report on that area as yet.

We have issued a preliminary report on the Pensacola area. All of this data is, of course, available to the correlating agencies who have had it made.

I am sure that the U. S. Engineers' Office, the U. S. Geological Survey, and your own good agency here, Central Florida, Inc., and your League of Growers, and others, can bring in much information and data that will be helpful at the next session of the Legislature.

Chairman Roberts:

Are there any questions of Dr. Gunter?

From the Floor:

I would like to say that our water supply is a different thing from irrigation—just the opposite. In the Midwestern States it is a question of getting water and storing it for irrigation. In those Western States the Legislature actually made a sufficient appropriation for stream measurements. Thus, in the state I came from, if a person wanted some particular information, he could find 10 or 15 or 20 records on a particular stream so he could know exactly what was going on.

I came to Florida 15 years ago. When I came here I could not find a record that would give me any idea as to the discharge of any of the streams in the State, and I think it has been largely my influence that encouraged the U. S. Engineers to employ experts on their stream measurements. Since I came here the U. S. Engineers have employed help or cooperated with the U. S. Geological Survey to carry on this work.

I would like to see the State of Florida—the Legislature of Florida—make a blanket appropriation, which the United States Government would match through its Geological Survey, so we could have complete and systematic measurement of all the streams in Florida.

Our water resources are most important for the development of the State, and it would be of inestimable benefit to the State to have that survey, and I think the Legislature of Florida owes it to the citizens of Florida to make such a study.

CHAIRMAN ROBERTS:

Any other remarks or questions?

The problem in Florida, of course, is to store our water so as to have it for irrigation or any other use. The part the State Agricultural Experiment Station may play in all this, and does play, will be explained by Dr. C. V. Noble, who speaks for Director Mowry.

FLORIDA AGRICULTURAL EXPERIMENT STATION

DR. NOBLE:

There has been a lot of pinch-hitting here today. I am pinch-hitting. Director Mowry was unable to come, so I am the pinch-hitter. Even though I don't make first base, perhaps I won't strike out.

I am glad to see so many here, and to hear so much very definite evidence that we are becoming water conscious.

This is a comparatively new development for our State and something should be done about it at the earliest moment. In order to take up but a few moments of your time, I have jotted down what I consider to be some of the potential assistance that the Agricultural Experiment Station might offer in this work.

Up to date, the Florida Agricultural Experiment Station has not engaged in any direct research work in water conservation and control, but there are many ways it can help in this work. These I would like to list for you in the following order:

1. Close cooperation of all research workers in agricultural research with the authorities having this tremendous task in hand to see that measures taken will be beneficial to agriculture in its broadest sense, including farm crops, horticulture, livestock production and forestry. At times the needs for water control to protect human life, to furnish city water supplies, for navigation, for water power and for other purposes do not meet the optimum needs for agriculture. All facts obtainable should be presented to the engineers and the best possible plan prepared for all interests concerned.

2. The Florida Agricultural Experiment Stations have not inaugurated research work in Agricultural Engineering. A corps of agricultural engineers could summarize the needs for all agriculture and forestry interests for intelligent cooperation with the central engineering authorities. The need for agricultural engineering research at the Stations is acute.

3. An evaluation of the economic needs for optimum water supply to additional acreages of land for agricultural purposes should not be neglected The prosperity of agriculture will depend upon keeping this industry in proper balance with the economic food and fiber demands of consumers.

4. More research should be aimed at determining the optimum water table for the economic plants of Florida that would result in increased quantity and quality of crop production. This would serve as some hing of a guide for the proper seasonal distribution of Florida's ample though irregularly distributed rainfall.

5. In summary, all available research relating to Florida water control should be reviewed and exhaustive research should be continued in all fields of endeavor to evaluate the benefits to be derived from definite changes in the water table. No action program should be started until a reasonable background of facts is at hand from reputable research sources.

CHAIRMAN ROBERTS:

If there are no questions we will now hear from our next speaker, Professor of Silviculture at the University in Gainesville, Mr. R. H. Westveld.

FLORIDA SCHOOL OF FORESTRY

MR. WESTVELD:

Facts about the forests of the United States, although incomplete and ever subject to revision, are nevertheless abundant. In a broad way we understand their

importance in the economy of land use and in industry; we have some knowledge of the regeneration and growth requirements of individual species; we have much factual data on the chemistry and physics of wood as a raw material; and we know the value of forests in water conservation and flood control. Let me repeat, we understand our forests and trees in a broad way. In specific instances, we understand them in considerable detail. However, when we focus attention on the forests of Florida, we find, with possibly one exception, naval stores, that specific data are very meagre. If we narrow our attention to the Kissimme Valley we find little information to guide us.

The School of Forestry was established in 1937 primarily as a teaching unit of the University. Such limited time as may be available for research must of necessity be spent in the immediate vicnity of Gainesville. There has therefore been no opportunity to study at first hand the forestry problems of Central Florida.

The Florida Forest and Park Service, organized in 1927, is primarily an administrative organization and probably only one member of its staff occasionally does a limited amount of research.

The Southern Forest Experiment Station, established in 1922 with headquarters at New Orleans, is responsible for the forest research carried on by the federal government in eight southern states, including Florida. A sub-station at Lake City has concerned itself chiefly with studies of forest management for gum production.

Obviously forest research in a broad sense has been badly neglected in this State, in consequence of which most of the forestry problems depend for their solution upon experience and personal opinion, rather than upon facts. Obviously this situation is a distinct handicap when trying to find a solution for problems of far-reaching importance.

In 1938 *Forest Resources of Central and South Florida* was published by the Southern Forest Experiment Station. This report, based on an extensive survey, gives factual data on the area and condition of forest land, the volume of timber of different kinds, its growth, and the drain on the forest resources resulting from cutting, fire, insects, and other causes. In this report, Central Florida includes 20 counties lying generally north of Lake Okeechobee, and thus including the Kissimmee Valley. This report is valuable in giving an over-all picture of the value and importance of the forests in the economy of the region and in depicting the unsatisfactory forest stand conditions brought about by poor land management practices. This survey might be of considerable value as a foundation upon which might be built a more intensive survey of the Kissimmee Valley to determine specifically what contributions the forests are making to the economy as well as to the water conservation problems of the valley and what their potentialities along these lines are.

The bulletin just referred to is the extent of published forest data for Central Florida. The neglect of the forests of Florida by existing research agencies is strikingly illustrated by the failure of a bulletin entitled *Check List of Native and Naturalized Trees of the United States, Including Alaska*, published in April 1944 to distinguish the so-called slash pine of southern and central Florida from the slash pine of northern Florida and farther north. Those of us who work with them in the field know that these two trees have different characteristics and behave differently, yet we are informed that there is only one slash pine.

In a bulletin entitled *Forests in Flood Control*, published in 1936, there is outlined the research projects in flood control which the 12 federal forest and range experiment stations propose to undertake. No projects are proposed for Florida.

If the record of the collection of forest facts in Florida in the immediate past is an index of what the future will bring, it would seem to be high time for the State, through its research organizations, to plan for a definite program of forestry research.

Of the area included in the Kissimmee Valley, probably at least 75 percent originally supported forest. The forests were composed chiefly of pines and cypress, but numerous hardwoods were locally abundant. All of the land area originally occupied by forest is no longer used to produce forest trees. A limited acreage has been cleared and the land devoted to citrus groves, cultivated crops and improved pasture. A much larger area has, after heavy cutting and burning, been providing subsistence range for cattle. The remaining forest land, by far the largest in area, is still devoted to timber production, but much of it is very sparsely stocked with trees. Thus, the whole forest environment has been greatly altered by man's activities. The virgin forests had an influence on the soil, climate, streams, and the whole water regime which was unquestionably different from that of our present heavily cut, burned, and otherwise mismanaged forests. In considering the problem

of water conservation and flood conrtol for the Kissimmee Valley we might very well ask the question: What effects have the changes which the forests have undergone in the past 50 years had not only on the forest environment but on the streams and lakes and on the agricultural environments with which forests are intermingled? This is the first of several questions that I would like to leave with you for serious thought and consideration.

As a corollary to the first question, we might ask: Is it enough to consider only the forest lands of the Kissimmee Valley? Is it not conceivable that the forest lands of the entire State may bear some relation to the water problems of this Valley. Possibly the condition of the forests in Jackson and Columbia County, though far-removed from here, may in some way affect temperatures, winds, precipitation or other climatic conditions which may be important to the agriculture of this area. At least let us not overlook this as a possibility.

Uncontrolled fire is a tremendous force in Florida's forests. It has been the most important single factor in preventing natural regeneration of our forests. Under protection from fire, reproduction generally takes place quickly and abundantly, and soon the needle fall develops a protective, water absorbing cover on the soil. If left unburned indefinitely such forests may become great fire risks. Consequently periodic controlled burning may be desirable to alleviate the fire hazard. What is the loss in water-conservation and flood-control value when forests are sparsely stocked because of fire, let alone the loss in economic value? Is complete protection year after year best from the water conservation standpoint? If so, is the risk too great? What would be the effect of periodic controlled burning?

The value of tree windbreaks in ameliorating the drying effects of wind, in modifying the effects of frost, and in giving protection in other ways is well established. Many citrus growers have found windbreaks useful in these ways. Do we know as much as we should about the beneficial and detrimental effects of tree windbreaks in the Kissimmee Valley? What relationship, if any, do they bear to the water conservation problem?

While properly managed forests may aid in water conservation and flood control in the Kissimmee Valley, the fact should not be overlooked that these same forests, while serving this purpose, can be valuable economic assets which supply vital raw materials for industry and for the cattle and citrus growers. Cattlemen are fully conscious of the utility of the forests in supplying fence posts. They realize, too, how suitable materials for this purpose are becoming scarcer with the disappearance of the virgin forests. The citrus and vegetable industries are dependent on the forests for packages. A strong economy demands that full use be made of all natural resources. So long as the annual growth per acre is only 24 board feet or .08 cords, as it is in Central Florida, we are a long way from this goal. The soil is probably capable of producing ten times this amount of wood. Some of the least productive forest areas are low in wood production because they are burned annually for grazing use. Shouldn't we find out which of these areas are most profitable for the growing of trees and which for pasture? Possibly a comprehensive land-use study would lead the way to better and more profitable use of the land resources as well as more effective water conservation and flood control. It is conceivable that on some areas forests can be managed very intensively at great profit while on other areas only the crudest management is practicable because of the limitation of natural factors. On these latter-type areas, could wildlife management be combined with commercial timber growing to attract the sportsman and tourist?

It should be obious from the questions which I have raised that we lack factual information on the forests of the Kissimmee Valley. Only through a comprehensive program of forest research can these facts be secured. The Florida School of Forestry is ready to do its part in collecting facts about the forests of this area which may help to solve the problems under discussion. Adequate data on the forests will not only be invaluable to the forester, but should be equally valuable to the farmer, be he cattlemen, citrus grower, or vegetable grower, to the engineer, and to the land-use planner. The forests do not stand by themselves as separate units, neither are the forestry problems independent of other land problems; they are interwoven with the whole agricultural and economic structure of the community, and with the problems of soil and water conservation and flood control. The support of you as individuals and of this organization are essential if forestry research as visualized by the School of Forestry is to become a reality, and if we are to make our proper contribution to the solution of land problems.

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Chairman Roberts:

Are there any comments or questions?

Mr. Cooper:

Mr. Chairman, I have something to say. As part of the ground water problem, we want to install recording instruments on wells throughout the Florida peninsula, and it occurred to me that some of the men here today might help us considerably in getting that work started.

We will need for this purpose artesian wells, preferably with pipes 8 inches or more in diameter, presently not in use. Where no existing wells are found for this purpose, we shall have to drill them. Thus, if we can find proper-type abandoned wells, it will save us money and serve the purpose. Mr. Williams tells me that he has one on his property which will suit our purpose. We want to get them well distributed over the Florida peninsula.

Mr. Scott:

You may not be familiar with this, but at the time of the initial survey for the Florida Ship Canal, the U. S. Engineers started observations all along the proposed water route, and also branched out over the state. Those readings have been taken once a week, or, in some instances, once a month since then.

At the present time we have one man on that job at Ocala, who reads a certain number of wells scattered over the entire state, except in the Miami area, once a week—that is the elevation of the water in artesian wells—ground water wells. That data is collected, and is on file at our Ocala office, and I believe anyone interested in that data could have access to it for examination, either there or at our office in Jacksonville.

Chairman Roberts:

We have included in this list of agencies one that is known as the Soil Conservation Service, a bureau or division of the Department of Agriculture for cooperation with State agencies in this important field of work.

While there is not as much erosion in this State as elsewhere, we do lose soil by slow oxidation, as when muck is exposed, and rapidly when it gets on fire. Soil is no good as soil unless it has water, and, of course, those who are engaged in the survey for the Soil Conservation Service are interested in water con rol, either by drainage or storage or by some other plan. What the Soil Conservation Service does along that line will now be reported to you by Mr. Robert Witherell, in charge of the work of the service in this area.

U. S. SOIL CONSERVATION SERVICE

Mr. Witherell:

I am sorry Mr. C. D. Gunn, our State Coordinator, is not here as scheduled as I am not sure what he would want me to talk about.

As the Chairman has already told you, our agency is a Federal agency. We are primarily working now with locally organized Soil Conservation Districts. A Soil Conservation District is, of necessity, organized by local people, and usually on a county basis. However, a Soil Conservation District does not have to be confined to a county. It can be related to a water-shed. The work of our office, after a Soil Conservation District has been organized, is to assist the locally elected officials of the District in developing feasible working plans for farm lands. Our Service is in a position to give the local Soil Conservation District such aid, engineering, agronomic, etc., as may be found necessary.

Where the U. S. Engineers leave off, our Service takes over. That is about all I can say, except I would like to stress the point Mr. Scott of the U. S. Engineers made about stream measurements. That is very important. I believe we should have all of our streams measured. We will need such information to solve our soil and water conservation problems in the future.

CHAIRMAN ROBERTS:

It has been demonstrated today that there are many different factors and many different departments of science that need to be coordinated to solve our problem. Thus, there are geological problems, chemical problems, engineering problems, and many others, the solution of which must contribute to a proper outline of the final solution, and all of which might be listed under the one head "Agriculture", because none of those things mean anything unless the agriculture of the state -our livestock, our citrus, our vegetables, our sugar cane, are enjoying the right conditions under which to develop. And so what the Agricultural Extension Service may contribute as the information arm of the College of Agriculture will be discussed by Mr. William Nettles of that service.

THE AGRICULTURAL EXTENSION SERVICE

MR. NETTLES:

I have been hearing a lot of good talk today about the need of water control, need of water conservation, too—too much water in one place and too little in another, and I could not help but think of a little situation that came to my attention right down by Okeechobee several years ago. It was in the spring-time, and there had been a pouring down rain for weeks, and water was standing everywhere. I met a good friend of mine, a cattle-man, Leland Pierce. I said: "Leland how is the cattle business?" He said: "The water is standing so high in my pasture that the catfish have started sucking my cows." It is somewhere between too much water in the pasture and too little water on Mr. Brown's grove that the real problem lies.

It is going to challenge the best brains in Florida to coordinate those different interests and work out a solution of the problem that will be practicable and usable.

Now, I know we went crazy a few years ago, and drained too much—everything was drained. Some parts of Florida today are in just about the same place that the poor old man was who had a facial paralysis. He went to prayer meeting and the preacher was asking for testimony from the different folks. This old gentlemen, with his face all drawn up, said nothing. Finally the preacher said, "Brother Jones, we have not heard a word from you tonight. Hasn't the Lord done anything for you?" The old gentleman got up and said: "He dern near ruined me."

It's a problem. As the Chairman said about the different organizations, it is going to be through the coordination of the findings of those different organizations, each finding its place and playing its part, then we will be able to put up a solid front and work this thing out.

In the Agricultural Extension Service we always speak of the County Agent as the key to the Extension Service. He is not only the key, but the door itself. In fact, he is the only one of the bunch who works much. I want to say this to you. The County Agent, folks, is the greatest teacher on earth.

The teacher or university professor can say: "Young man, I have a lot of information for you which I can give out to you. If you can absorb it and pass an examination, then you can go out and see what you can do. If you can't absorb it, you will get thrown out of here."

The County Agent has not only to be a teacher, but his information has to be practicable and usable. However, he doesn't stop there. After he gets his information, he has got to inspire the student to put it to practical use. If he can't do that, the student throws him out.

Someone made a remark awhile ago about a lack of understanding among the farmers and growers and others about this soil conservation and water control problem. I want to say this—speaking about the potential work the different organizations can do, if we can work out a practical, usable program, there is no group of folks in the world that can help us get understood quicker than the County Agent due to his close association with the farmer. If we can get a workable program, the Extension Service, through the Couny Agent, can get his quick understanding, as no other individual in the community.

The Extension Service is tied up with the Soil Conservation Service. It assists in organizing the districts. The County Agent is Secretary and the Soil Conservation

Survey is geared to play a very active part in this work we are talking about today. Consequently, the County Agent, through his cooperation and his close contact with the farmer can be one of the greatest factors we have in getting this program across.

I thank you.

CHAIRMAN ROBERTS:

I see a few County Agents who look much more inportant than they did a few minutes ago.

GENERAL DISCUSSION

CHAIRMAN ROBERTS:

Before opening the subject to general discussion I wish to give a little history.

A year ago last July, a group of men who looked upon themselves as leaders, met up in Sanford and organized what is known as Central Florida, Inc.

The purpose of that effort was to unite into one group all the forces in Central Florida that are working on some phase of this water situa ion—Mr. H. C. Brown and others who had flood control on their minds like Mr. Davis, who dodged out, but we made him an officer, anyway.

Our purpose then was merely to relieve an acute situation that existed in what we regarded as eleven counties in the citrus belt—the Kissimmee Valley on one end and the St. Johns on the other.

We got the sympathy and endorsement of those various groups, and then we thought we could go ahead, and to our amazement, this movement has spread. Some statewide organizations have wanted a part in this—not only in Central Florida, Inc., merely, but to carry out our original proposal to statewide proportions, and I am very much gratified to see how that idea has received support in all directions.

We have received into the fold the Farm Bureau, which has adopted this as one of its major objectives. We also have the interest of the State Planning Board. Mr. Treadway could not be here today, but he has been a power behind the scenes in bringing into focus certain questions leading up to action. So, while I don't claim that without Central Florida, Inc., it would not have been done anyhow, I do say those plans we have for eleven counties have become statewide. I am gratified this has become true.

We have not yet heard today from the Chairman of the Water Conservation Committee of the Farm Bureau. He is not like myself, merely one who realizes the need without doing anything about it. He has worked very hard to develop and advance the program at all times.

As I understand it, and he can correct me if I am wrong, this is not a selfish program in which the Farm Bureau alone can work, but behind which the Farm Bureau wishes all the forces in the State to gather, and to utilize all the different factors, including the Legislature, etc.

Recently in Tampa, before a group of leaders from all over the State, there was adopted a resolution introduced by Mr. R. D. Keene of Orlando, calling for the establishment of a Statewide Authority with plenary powers, so that the State would be in line to do anything about its water problem as fast as the plans for these projects are completed. In this way, as they arise, they can be taken care of; and that also calls for money.

In addition to that, there has been introduced into Congress a resolution passed by the House, and favorably reported by the Senate, which calls for a survey by army engineers of these eleven counties. That can very easily be understood. Those eleven counties are where we thought the water failure most acute.

Here on this divide on which we now sit is where the waste begins, and we should begin to save our water here, and save it progressively down to the lower levels. While I am on that subject, I am reliably informed that Col. A. B. Jones, our District Engineer at Jacksonville, is very thoroughly committed to the idea we have in mind, and would like to do something about it.

When the war broke out, the engineers were all taken off the survey, especially in the Kissimmee Valley and also in the St. Johns Valley, and in the territory between these two valleys, and I am informed that Colonel Jones would not be at all displeased if you write to him suggesting that, as engineers become available, they be put back to work on this survey. It is a wider scheme than these eleven counties. So, if you will write to Colonel Jones, it will not offend him a bit, and he will have a leverage with which to appeal to his superiors to bring into this area engineers now being released from army duties.

The gentlemen I have referred to will tell you something of the plans and attitude of his committee, Mr. Lacy Thomas, at present a member of the Legislature.

MR. THOMAS:

I have enjoyed this discussion. In the beginning, I would like to endorse all that Warren Roberts has said about Central Florida, Inc. I think the organization has rendered invaluable service to this cause.

Chairman Roberts, in particular, has kept the flame burning and has conducted an educational program, which is showing results.

The coming of the Farm Bureau into the picture is in an effort, not in any sense of the word to take any of the glory from Central Florida, Inc., or any other organization which has been leading the grand work. The Florida Farm Bureau is only about two years old, and it is only about a year ago we decided that something should be done about water conservation, and they happened to pick on me to help do something about it.

I have sat in on many meetings since then, and have given the subject careful study. It occurs to me and the members of the committee that the time is ripe for organization. It is time to begin to do something. Many studies have been made. There are some things which we definitely know can be accomplished at the present time and under present conditions. There is a need for continued study. That will probably continue—we will need to continue to study the subject until the end of time and continue to modify the position we take. We don't expect to go out in 1945 to the Legislature and ask them to draw a set of laws which will cure the problem, but we do hope we can correct some things which are now apparent.

The State Geological Survey has rendered valuable service through the years, which in many instances is the basis upon which we can act at the present time. I think they could have done more than they have done except that, as Mr. Gunter, who is a very modest man, has indicated, they have been short on funds. Now he is only asking for $19,000. That's not enough to work with.

He is handicapped by one other thing—the name of his department. The average person, and I classify myself as such, when you say "geologist", he thinks of a study of fossils or age-old rocks, or that sort of thing. While I didn't know that Dr. Gunter had done so much in the field of water conservation, I do find that he has been doing something besides studying age-old rock formations of Florida. He has been learning something about our water supply problem. However, I think it would be an advisable thing, in all deference to his department, if it changed its name.

That was one of our reasons for suggesting that an agency be set up to study this problem, and give it power to act, always considering the interests of the individual groups, and I believe something like that can be done.

We have made our recommendations quite general, because we feel it is going to be the function of the committee to determine the form it should take. They may take the Department of Geology and extend its powers and functions, or start another department, of which the Geological Survey would be an important part. There are many directions it can take. Our committee only set out to bring together all these organizations and forces interested in conservation and get them behind the thing so that something will be accomplished. That is what caused us to call the meeting at Tampa last Monday at which we asked for cooperation from all groups in the State, and in which there was an open discussion. Out of that meeting came the recommendation that Governor Holland and Governor-Elect Caldwell, together, appoint a group to study the situation and present a suggested law to submit to the Legislature. When they have done that I think it will be splendid if the committee brings it back to that group of agencies represented Monday, for approval, rejection or modification. Then we should get behind it, get behind the Legislature to enact it into law.

As Governor Caldwell said this morning, they cannot collect and analyze this data and write the law themselves. It will be very helpful if this "spade-work" is done beforehand. I know the lawmakers in Tallahassee will be only too glad to do something for us.

The Farm Bureau's function was to bring these agencies together and get something going, and we felt we could take the lead because we do represent the biggest single interest in the state—Agriculture. We had no ambitions—nothing up our sleeves—only a purely unselfish and impersonal thing—happy the matter has been brought up to this point. And I believe, with the cooperation of this group, and the others in the State, we will accomplish something of benefit to Florida.

I hope this organization will endorse the stand taken by the group last Monday in Tampa.

Chairman Roberts:

I think my remarks were misleading. The motion referred to was to have a Legislative Committee appointed by the Governor and Governor-Elect, who would prepare a legislative program for the next session, and refer it to their various groups for endorsement.

We have here today a man who is really a veteran in this sort of thing. I suppose he knows more about the law—the procedure, the best way of getting things done by the government than any other lawyer in Florida.

When I first knew him, I breezed down to Kissimmee and sat in on a meeting, but I didn't know him, and he didn't know me. At that time, he was presiding as chairman of a meeting of the Kissimmee Valley Flood Con rol Group. There were several on that committee—among them Mr. John Miller of Orlando and Erlo Bronson of Kissimmee; and there were one or two gentlemen from Lakeland. I was also on it, though I don't know why. The chairman of that group will now address you, and I wish to say that if they try to formulate a legislative program, without asking his advice, they will be making a serious mistake. Mr. Ellis Davis of Kissimmee.

Mr. Davis:

Mr. Chairman, and gentlemen of the State, I came to this meeting for the purpose of trying to absorb some knowledge rather than to try to disseminate any on the subject of flood control and water conservation. The plan is old to me, because I happen to live in an area there, where, at times, we are marooned, and at other times, dry as a powder keg.

My observations on this subject have been developed purely as a man sitting on the sidelines—not as a farmer of any sort or a producer of citrus crops, or livestock; but I have tried to understand some of the problems that each group has been confronted with. I have tried to maintain the position that we should be able to work in harmony with what the other fellow wanted to do in his area on the subject of flood control and water conservation and try to persuade him to do likewise with us.

I have also adopted the attitude of avoiding, if possible, a conflict between state and federal agencies which would have these subject matters for considera ion.

It has been my privilege for approximately 17 years to work in close harmony with the War Department Engineers, at their District Office in Jacksonville My associations with them have been most pleasant, and I feel that the people in Florida who have flood control and water conservation as a constant problem, are indeed fortunate over a period of years in having had in the District Office in Jacksonville engineers who were sympathetic enough to understand our problems and to really give those problems some real thought They are today in possession of a vast amount of information—field information, and information from an economic point of view.

It is my considered opinion that in this state we should encourage the Jacksonville engineers to resume, as soon as possible, a study of our flood control and water conservation problems, as it would be most helpful. I also believe that if you will offer your services to those engineers to supply them with factual information, it would tend to justify the Federal government in making a sufficient appropriation for further survey—that it would go a long way toward helping us.

I came into Central Florida, Inc., somewhat by draft for the purpose of trying to see the over-all flood con rol and conservation ideas worked out in Central Florida, and in other parts of Florida, because I am inclined to believe that we will always continue to have normal, average rainfall in this area. We have had since time immemorial. I am not afraid of the disappearance of an adequate amount of fresh water in peninsular Florida at any time in the near future. However, I do feel that we can utilize our supply of water to better advantage with more appropriate controls than are now being used.

The subject of control, in my judgment, is largely a matter for the Engineering Department. The interests that will be affected under any system of control is a matter that I am not able to fully determine. It is impossible for me to see how this man will be affected here, and that man affected there. All that I am sure of is that in solving the problem, an attempt will be made to see that the greatest good for the greatest number results.

I would also like to see the District Engineer's Office advised by this Society of its willingness to help them to obtain factual information as a basis for Federal expenditures for this survey, and probably—most likely, in fact—appropriations for flood control will follow, so that by the system of trial and error, so to speak, the initial program, as it goes on, will be more and more perfected.

I am convinced that the control and conservation of the water of the Kissimmee watershed is vital. I believe that this control can be established with an expenditure of funds that will fully justify its construction.

We Floridians, in my opinion, should not at this time be able to seal ourselves into a bounded district 90 miles by 40 miles, with sufficient funds to meet the costs of any control program that the War Department Engineers would approve and supervise its construction.

Therefore, of necessity, we must look to the Federal government to help us, because there may be things we might be called upon to supply that we could supply within our limits, such as for instance roadways, or the maintenance of roadways where shallow channels might be constructed, or channels where navigation might have to stop, a bridge-tender, or something of that kind. These expenditures would be within our means and ability to pay, but as I see it, the over-all cost of the survey and the actual construction of the necessary safeguards needed in that watershed would be beyond our ability, and, therefore, a fit subject for Federal assistance.

This subject is so big that I am sure anyone attempting to speak on it is in danger of saying some things that are subject to controversy. This man may take issue with you on this subject or that subject, but if we are all in accord on the idea that productivity in our state is importantly tied into the control and conservation of our fresh water, let us hold these controversies as far away as we can, and meet and agree to obtain the main objective—control and conservation. Then let time help us to bring it to the point where we are justly proud that we have a control project in Central Florida, or any part of Florida, that is of great benefit, not only to the present generation but the generations to come.

I assure you it has been a pleasure to attend these meetings today, and I hope something useful and constructive will develop out of them.

Chairman Roberts:

I do not think there is any doubt about resumption of this survey by the Army Engineers. Mr. H. A. Bestor, drainage engineer for the U. S. Sugar Corporation, Clewiston, told me conservation plans are in the air, but just as soon as the war is over and shortages are replenished the work will be resumed.

Dr. Gunter, Mr. Ferguson and others have stressed the desirability of further surveys of a geological nature. I happen to know that a resolution is in process, for introduction into the next session of Congress, to authorize an extensive field study by the U. S. Geological Survey.

We will now listen to a very important discussion of how the problems of the Kissimmee Valley are related to those in the Everglades in matters of water control and conservation by Mr. W. Turner Wallis, Chief Engineer of the Everglades Drainage District. Mr. Wallis.

Mr. Wallis:

I was amused a few minutes ago when it looked like I would not be heard. The true facts of the matter are that I was put on the program by Dr. Allison in case he had to round the thing out. He didn't expect to need me. The last time he played me a similar trick I got to talk about 11:00 o'clock in the evening.

For the past 24 and one-half years I have been closely connected with, and, at times, to a very embarrassing extent, responsible for many of the mistakes that have been made in the attempt at reclamation and conservation of the Everglades area.

If you favor the belief that an expert is one who learns more and more about less and less until finally he knows everything about nothing, then you can count me as coming before you as an expert on Everglades problems. I know a lot about what not to do, but I know very little about the proper solution of these problems.

I didn't know what I was put on the program to talk about. Dr. Allison has suggested that I tell you what we have accomplished toward conservation in the Everglades. I said not to do that because our accomplishments have made a very poor showing; so it was not until I got the printed copy of the program I knew what my subject was.

I am frank to confess that I know but little of the problems of the Kissimmee Valley. I don't know what the relations are. I think they are many and varied, and I think the most important relationship between the Everglades and the Kissimmee Valley are the human relationships. You have a very difficult problem to evolve and plan, but the much more difficult problem, in our experience, is anything that has to do with making that plan effective over the antagonisms and suspicions that needlessly exist between different sections. We are faced with the supposed differences of interest which for the most part are more imaginary than real. A common solution of our problems definitely will be to the best interests of all groups.

I think the best service that the Everglades can extend to Kissimmee, or Kissimmee to the Everglades, is the development of such close working relationships that there will be knowledge in one area of what has been tried in the other area and succeeded or what was tried in there and failed. In this way it would seem we could prevent failure in other areas.

I don't know, but I think that most of the problems of the two areas can be much more expeditiously approached and solved separately. I think that while we are not too concerned with your problems we will benefit by anything you do toward the solution of those problems.

There are some phases of the general problem that are common in many aspects, and which can be jointly approached to mutual advantage. However, I do not think we are particularly dependent on each other for an approach to many phases. As a matter of fact I think we might encounter undue delay in an endeavor to reconcile all the differences of opinion on the plan in all of its details.

I think that about covers all I have to say.

Chairman Roberts:

The matter of the fullest possible coordination, at least ultimately, between the Kissimmee Valley area and the great Okeechobee basin and its original overflow area to the south is indeed important, as Mr. Wallis has so clearly indicated, if a workable program for the whole is to be evolved. If there are no questions or further comments I will now turn the meeting back to President Volk:

President Volk:

Our next meeting will be at 8:00 o'clock this evening when there will be a business session and meeting of the Executive Committee following a further discussion of our water control and conservation problems at the state-wide level by Dr. Gunter and Mr. Frank Holland. Unfortunately the travel plans of Mr. Malcolm Pirnie of New York who was to discuss domestic water supply problems this evening have become so completely snarled with priorities that he cannot be with us. However, he expects to stop in on his next trip south and discuss this phase of our over-all problem with us in detail.

Meeting adjourned.

Note: The addresses of Dr. Gunter and Mr. Holland, delivered in the course of the evening meeting, will be found on pages 8 - 10 and 11 - 14, respectively. The report on the Business Meeting will be found at the back of this volume, page 186. —Ed.

SYMPOSIUM: THE RELATION OF TYPE AND COMPOSITION OF SOIL TO PLANT, ANIMAL AND HUMAN NUTRITION

THE ROLE OF THE SURVEY IN THE STUDY OF SOIL IN RELATION TO PLANT, ANIMAL AND HUMAN NUTRITION

MATTHEW DROSDOFF *

The soil is one of the primary factors in determining the composition of a plant growing on it. It can be said that the well-being of animals and man is dependent on the capacity of the soil to supply to plants certain mineral elements in the proper amounts and proportions. As Browne (7) expressed it. the plant is the great intermediary by which certain elements of the soil are assimilated and made available for the vital processes of animals and man. The simple inorganic constituents of the atmosphere and soil are absorbed by the plant and built up into proteins, sugars, starches, fats, and other complex substances. These substances synthesized by the plant are subsequently transformed by the vital processes of the animal into bones, flesh, blood, and other materials. For these profound transformations to progress in a normal manner, it is necessary that the soil supply the required mineral elements in proper amounts and proportions. If there is either a deficiency or an excess of certain elements, abnormalities develop in the vital processes somewhere along the line and man is ultimately affected.

There is much evidence of the profound effects that the soil has upon plant and animal nutrition. Auchter (2), Browne (7), and others (6, 14) have discussed the matter and Beeson (5) has contributed an excellent comprehensive review of this subject. Most of the recent investigations have been concerned with the effects of deficiencies of certain elements, particularly the so-called minor or secondary elements, on nutritional disorders in plants and animals. Some outstanding work of this type with plants has been done here in Florida, as exemplified by the nutritional troubles in citrus due to deficiencies, such as "dieback" which results from a lack of copper, "bronzing" caused by a deficiency of magnesium, "frenching" due to insufficient zinc, and others. Among the vegetable crops commonly grown in Florida there are "chlorosis" of tomatoes on the calcareous soils resulting from an insufficient supply of manganese, "crack stem" of celery caused by a deficiency of boron, and the stunted growth of various vegetable crops growing on the organic soils of the Everglades caused by a lack of copper.

By no means are plant deficiencies common only in Florida soils. There is hardly a state in this country, or a country in the world that

* Associate Soil Technologist, Division of Fruit and Vegetable Crops and Diseases, Bureau of Plant Industry, Soils, and Agricultural Engineering, Agricultural Research Administration, U. S. Department of Agriculture.

has not reported on nutritional disorders in plants as a result of a deficiency of certain elements in the soil. The dry rot of sugar beets in Michigan, the crown rot of sugar beets in Ireland, and the internal cork of apples in New York and British Columbia are all caused by boron deficiency. Little leaf of peaches and other fruit and nut trees in California resulting from insufficient zinc, sand drown of tobacco in North Carolina due to magnesium deficiency, and yellows of tea in Africa caused by a deficiency of sulfur are only a few of the many disorders that have been reported.

Soil deficiencies that cause nutritional disorders in animals and man have not been easy to determine but there has been some outstanding work in this field. The classical work of the New Zealand and Australian investigators is well known in linking the cause of "bush sickness" of cattle to a lack of cobalt in the forage. Other mineral deficiencies in cattle resulting from deficiencies in the soil have been reported in many states and many countries. Important work in this field has been done here in Florida, the common salt sickness of cattle having been traced to deficiencies of iron, copper, and cobalt in the soil (4). Nutritional anemia among rural children in certain areas of Florida has been correlated with the soil from which the children derived the major portion of their food (1).

Although the literature contains much evidence of the importance that soils play in plant and animal nutrition, the data are too often insufficient for translating the results of the experiments into practical recommendations for agricultural practice. One difficulty has been that the soils investigated are not always described or defined in a way that permits the observations to be extended and generalizations made. The soil descriptions are frequently too general and refer rather to the geological materials from which the soil is derived as, for example, "lime-soils," or a single-value descriptive designation is given, such as "dark colored soils." It is obvious that if practical applications are to be made of the researches on soils as related to plant and animal nutrition, it is of utmost importance that the soils on which the work is done be accurately defined within a scientific system of soil classification. Otherwise the investigations in this field can have only limited meaning and application.

The system of soil classification now used in this country is built upon a knowledge of the physical and chemical characteristics of the soil. These characteristics include not only those which can be described in the field but also those which must be determined in the laboratory. Although it is recognized that all of the important characteristics should be taken into consideration in the development of a scientific system of soil classification, much information is not yet at hand and needs to be acquired. This is particularly true of laboratory data on physical, chemical, and microbiological properties as they relate to the morphological characteristics observed and described in the field. But as Kellogg (12) points out, scientists in every field of soil science must help build and refine the system of soil classification so that it will clearly define the relationship between different soils and be usable in guiding future researches.

In the United States the principal unit of soil classification used in connection with soil, plant, and animal research is the soil type (3). The soil-type name consists of a series name plus the textural class name of the surface soil. The series name defines the differentiating characteristics of the soil profile including texture, color, consistence, structure, and nature of the parent material. When one soil differs significantly from another in any one or more of these characteristics, then it is of a different series. For example, Orlando sand, though of a texture similar to Blanton sand, is much darker in color especially in the surface foot of soil due to a higher content of organic matter, which is reflected in the greater inherent productivity and quality of crops grown on the Orlando sand.

With an adequate system of soil classification at hand for defining the soils with which we are working, it then becomes necessary to know the distribution of the various soil units in order to extend and enhance the value of any knowledge obtained. This, of course, requires the making of a soil map which is a representation on paper of the distribution of the mapable soil units, primarily the soil type. The soil map delineates those soil areas that possess similar characteristics and thus serves as a guide in either initiating research or extending the results of investigations to practical ends.

From this discussion it is apparent why a soil survey, i.e., the determination and mapping of soil types, must form an integral part of any research program involving the study of soil, plant, and animal relationships (13). Actually the classification and mapping of soils is the foundation upon which rests the extension and practical applications of all such research investigations.

As stated in the official Soil Survey Manual (11) of the U. S. Department of Agriculture: "The objects in soil surveying are (1) to determine the morphology of soils, (2) to classify them according to their characteristics, (3) to show their distribution on maps, and (4) to describe their characteristics, particularly in reference to the growth of various crops, grasses, and trees." These objectives are brought to focus in the soil map and its accompanying report. The soil map shows the location and extent of the various kinds of soils that can be defined in sufficient detail so as to indicate differences of significance with regard to the growth of plants and use of the land.

Some investigations in recent years have already produced sufficient evidence to show that nutritional problems can be definitely related to clearly defined soil units, primarily soil types. Much of the research done here in Florida has had as its objective the relation of soil types to nutritional disorders in plants and animals (1, 4). This is the only way in which rapid progress can be made in this work. Data accumulated on plant and animal nutrition in reference to soil types can readily be extended throughout problem areas. Predictions can be made with the use of a soil map as to the likelihood of occurrence of such areas. Even without an available soil map but with knowledge of the soil type relationships, generalizations can be made. The ultimate goals, however, cannot be reached until we have all of our land delineated in clearly defined units on a soil map.

If we assume that the ultimate objective of our investigations on soils in relation to plant and animal nutrition is to promote the well-being of all the people, it is not likely that this goal can be reached without the information that the soil survey furnishes being available on all of our land. A knowledge of the extent and distribution of soil units can serve as a guide in determining whether or not to concentrate the research efforts on certain areas. For example, a nutritional disorder may develop in a certain locality on a certain type of soil; but if this soil occupies only a limited area or for some other reason is not important, then from a practical standpoint it might be less worth while to expend our much too limited energies and resources on the problem than if the problem soil represents great areas or if it is probable that the results obtained can be widely applied.

Perhaps, by way of illustrating some of the points that have just been mentioned, it may not be out of place here to discuss some of our mineral nutrition work with tung trees. In the early part of August 1941 our attention was called to an abnormal foliage condition in a limited area in a tung orchard near Capps, Florida. The nature of the disorder suggested that a mineral deficiency might be involved. The soil in the area is Red Bay fine sandy loam which is considered one of the soils most suitable for tung trees. Furthermore, extensive tracts of this soil type and closely related types have been planted to tung. For these reasons it was deemed important to immediately conduct investigations as to the cause of the disorder and the corrective measures necessary. From the knowledge about the soil type involved it was felt that the results of this research would have wide practical application. This was in view of its wide distribution, the extent of tung plantings on it, and its potential possibilities. By means of leaf and soil analyses and field experiments the trouble was found to be due to a deficiency of potassium (8, 15). Meanwhile a survey was made of the tung plantings located on the same or closely related soil types and the disorder was found to be widespread on these soils. Recommendations were made to the growers having orchards on the affected soils to increase materially the percentage of potash in the fertilizer mixtures, and by following this suggestion the previously affected orchards are now, three years later, developing satisfactorily. As a result of our experiments and the experience of the growers and with knowledge of the soil type relationships, we can more accurately predict the fertilizer requirements to meet the nutritional requirements of tung trees on the Red Bay fine sandy loam and related soil types than could be done without such knowledge. Then, if there were available soil maps on which would be delineated all the areas of this and closely related soils, the results of the work would have their maximum utility.

Our work on nutritional disorders due to magnesium and copper deficiencies has followed a pattern similar to that described above for potassium (9, 10). We have correlated the occurrence of these deficiencies with definite soil types so that we have been able to extend the results of the investigations to many tung plantings on similar types of soil. Without a working system of soil classification and without any available soil maps we would not have been able to bring to final fruition in a practical way our investigations on nutritional disorders. These same principles are applicable to all investigations involving research on soil

as related to the nutrition of plants, animals, and man and the furtherance of our efforts in this important field of work is dependent in no small measure on progress in the field of soil classification, i.e., soil survey.

At the present time there are available soil survey data on only a few of the counties in the State of Florida. This work is continuing but when we realize the wide need for research on nutrition problems in this state, we can appreciate the vital importance of devoting more thought and energy to collecting more and more data in the field of soil classification and mapping.

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SOIL FERTILITY AND FOOD QUALITY*

Wm. A. Albrecht **

Food is the dominant factor in the control of all forms of life. Food stands out as the major objective of our struggles, whether in peace or in war. Reduced to its agricultural chemical fundamentals, food production is a matter of mobilizing some dozen nutrient elements into our bodies from the soil by way of plants and sunshine power. For nutritional service, these essential chemical elements must come, not singly, but variously and properly compounded. When synthesized into myriads of chemical complexes they serve to build the body and to keep it going. Their fitness as to supply in total amount and in proper chemical combinations determines the quality of our foods.

Every kind of creation starts with this handful of dust, or with the five per cent of vegetation, or finally of our bodies, that is the ash. It is this soil-borne mite that controls the fabrication of the other ninety-five per cent—that is four elements coming from air and water—into either mainly carbohydrates, cellulose, lignin, and wood of energy value only, or into proteins, vitamins, and more complex compounds of higher service in body-building. The soil fertility, or these mundane chemical potentialities of life, are then the real material basis of our bodies. We are, in actual fact created from the soil.

Plants Feed by Exchange, or by Barter with the Clay

Plants get their nourishment by means of chemical exchanges between the hydrogen or acidity on their root surfaces and the nutrients held on the surfaces of the innumerable particles constituting the clay fraction of the soil. Of the three soil separates, sand, silt, and clay, named in order of decreasing particle size, it is the clay that offers the greater possibilities of rapid chemical reaction. As for its own breakdown, the clay is a relatively inert mineral. But it is of infinitely small crystal size and holds on its immense surface in exchangeable condition the many elements of nutrient service to plants. It is there that these elements of service in feeding plants and peoples are held in this condition against loss by water as a leaching agent, but ready for a quick transfer to plant roots offering acid or hydrogen in trade. It is the clay with its supply of essentials that has adsorbed or taken these out of solution. It is the clay that is the jobber to provide the plant with its needs quickly when the growing root comes along. It is the clay, which within its own crystal structure offers a little, but which on its surface can hold much that has been given it, and which plays the soil's essential and active part in provisioning our crops at the high speed required during their short growing season.

The silt and the sand as minerals in the absence of the clay offer so little active surface, and are so insoluble that the root in direct contact

* Presen ed by Dr. Geo. K. Davis, Gainesville, in the absence of Dr. Albrecht.

** Chairman, Soils Department, University of Missouri, Columbia, Mo.

with them can get very little from their slow chemical breakdown. The sand, in particular, that has survived weathering forces to remain in particles of larger size, is naturally harder and more insoluble as this resistance to disintegration and decomposition testifies. Then, too, its main mineral constituent is quartz. This mineral carries no element of nutritive value. The silt, however, that is softer and is therefore more readily ground to smaller size by weathering agencies, is richer in nutient minerals and is more readily broken down chemically. It is, therefore, the soil's main reserve supply of nourishing elements in the rocks and minerals that by their slow decomposition keep these passing to the clay in adsorbed form for plant nutrient service.

Clay as the Jobber Handles Acidity as Well as Nutrients

It is this mineral assembly line that is giving supplies to the plant. The rock is passing the essentials to the clay and the clay is passing them on to the root. The root in turn is passing hydrogen, the acid element—and possibly other compounds—in the opposite direction. The root, as a growing body, goes through the soil only as it can do so, by growth. It does not advance into a sterile soil. As a respiring organism it gives off carbon dioxide, which unites with the water to form nature's widely disseminated and most common solvent, carbonic acid. This acid is the provider of the hydrogen, a very active element that is exchanged to the clay for the nutrient stock it carries. As the clay gives up its store of nutrients and takes hydrogen in exchange, this soil separate becomes more acid. The resulting acid clay, then, or acid soil in nature, is merely a soil of lower supply in fertility elements or in possibilities of plant production.

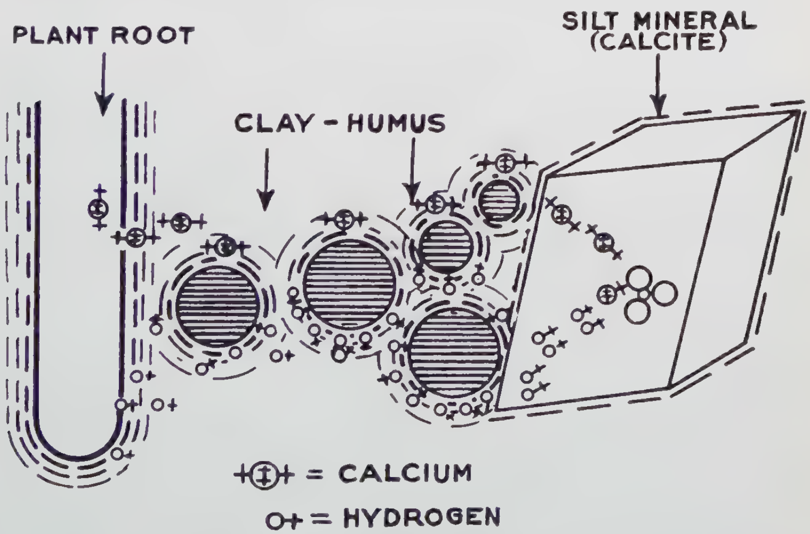


Figure 1.—Plant nutrients, like calcium, held on the colloidal clay or humus, are exchanged to the plant root for the hydrogen or acidity it gives off. As the nutrient supplies on the colloid become exhausted the excessive hydrogen substituted for them serves to break down the mineral reserves to pass their stock of nutrients to the colloid and to the root.

Soil Rest to Restock the Clay with Plant Nutrients

This acid clay, or this jobber that has traded its stock of fertility for acidity, must then take a rest from crop production while it trades its acidity for fertility in the silt reserve minerals to restock itself for more business with the plant roots. Natural acidity, then, is merely a case of significant depletion of the soil. It indicates that the clay is not quickly restocked from the reserve minerals and rock fragments. The soil's mineral assembly line that is ordinarily passing essential nutrient elements from the silt to the clay and then to the roots, is beginning to run too slowly and to deliver less. Soil acidity is merely nutrient deficiency of the clay and of the mineral reserves.

Humus, Too, May Be a Nutrient Jobber

In our virgin soils that have had myriads of generations of plants to come and go and to pass on their dead tops and incorporated roots as decayed organic matter to form colloidal humus, there was this stock of prefabricated soil fertility for our crops. As we plowed these virgin soils to fan the microbial fires of humus destruction, and to use this additional organic colloidal exchanger of nutrients taking hydrogen from the plant roots and breaking down the mineral silt fraction, we were running, at high speed, this humus assembly line that made for high crop yield. We had little thought of soil depletion. We worried little about impending deficiencies in the crops as animal feeds or as human foods. It was this destruction of natural humus in the soil that made such good crops on land freshly cleared of forest. It was this destruction that spelled early American prosperity and pushed high the unearned increments of our lands. It is this destruction that calls for soil conservation and soil fertility restoration today.

This high production of crops occurred on land that, without the drop of forest leaves as natural "forest manure" and as returning fertility to go into trees again, could scarcely produce even the wood crop by which few animals or higher life forms can be nourished. It is this waning humus supply in the soil that has been pushing nutritious vegetation westward except as the soil is bolstered up through lime and other fertilizers with the nutrients that make crops more than merely woody bulk of value only as fuel.

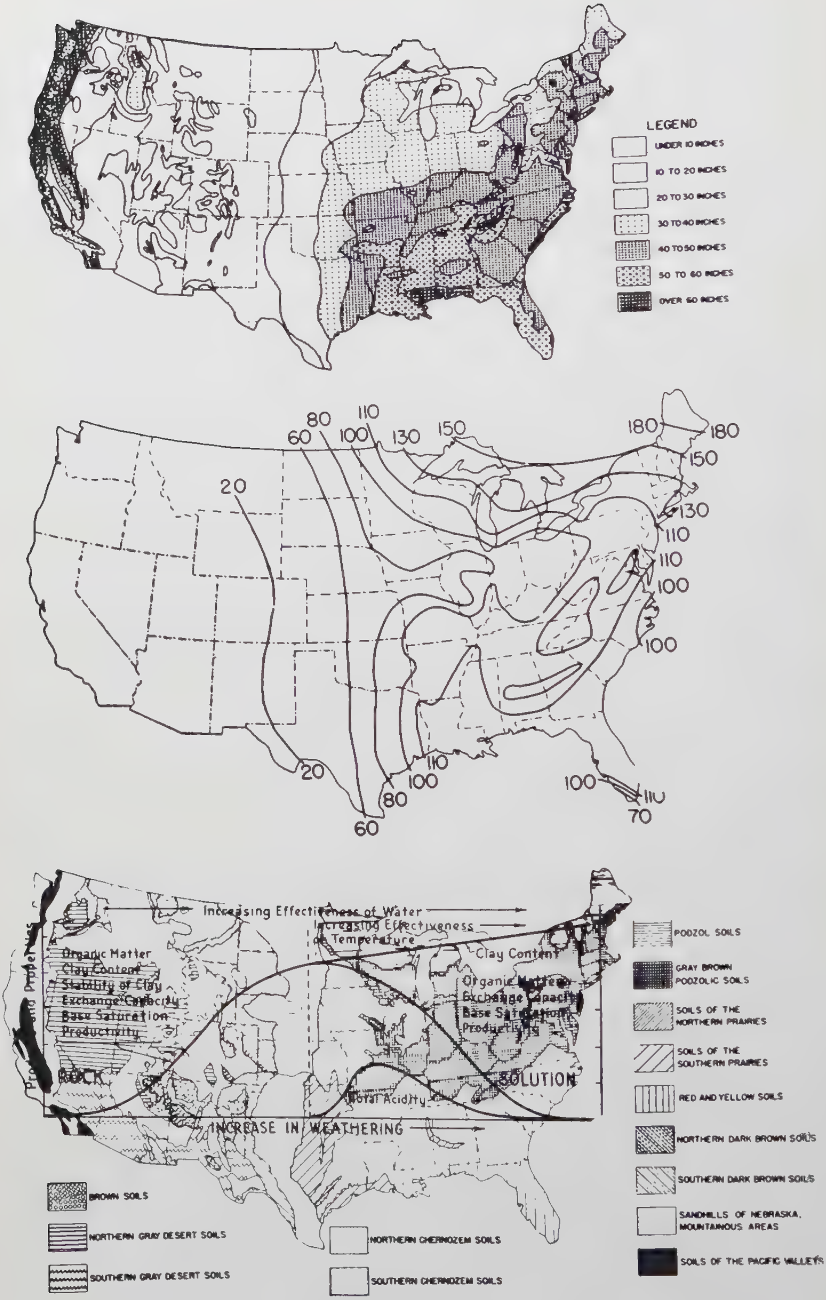
Restored humus by means of fertilizers and sod crops grown for that purpose is essential to keep this second assembly line running in our soils. As it runs almost empty there come in the less nutritious crops, or those which as volunteers in pastures are called weeds because their fabrication with so little soil fertility makes the animal disregard them even under the threat of starvation. The animal is discriminating against photosynthesis only and is looking for crops that also give compounds of biosynthesis. In our cultivated lands the grain crops, too, fail to yield regularly. Some of the soils have become alternate year yielders, as demonstrated by the plot in continuous wheat on Sanborn Field at the Missouri Experiment Station. This is bearing a wheat crop only every other year regardless of annual seedbed preparations and seedings. *Both the humus and mineral assembly lines need to be running at full delivery capacity for the higher yields of nutritious foods and feed from our soils.*

Differences in the Stage of the Soil's Development Give Differences in the Plant's Chemical Composition

Soil may be said to be a temporary rest stop of the rocks enroute to solution and to the sea. When the trip has just been started, the soil is not yet significantly developed. As the rock nears solution, or represents those remaining minerals of high resistance to weathering, the soil is overdeveloped. Thus, we may have soils *in construction* and *in destruction* in a geological sense. Soils at their best, however, are those with the rock broken down sufficiently to provide a fair amount of clay, and to have the adsorptive, or exchange, capacity of this soil separate fairly well saturated with the nutrient elements like calcium, magnesium, potassium, and others of positive electrical charges, and commonly called the bases. The better soils have not been weathered far enough to remove completely the softer rocks and minerals carrying the essential nutrients as reserves to be weathered out later. The silt separate still carries a supply of nourishing mineral reserves to be mobilized to the clay as it gives up its adsorbed nutrient supply to plants. Nor has the weathering gone far enough to load much of the clay's exchange capacity with acid, the non-nutrient hydrogen. *Better soils are midway between construction and destruction, both of which, as processes, contribute to the productive capacity of our soils.*

While soils are in construction, vegetation gains its foothold and starts to conserve fertility by combining it with carbon of atmospheric origin and to hold it as humus against the forces of destruction and removal. Soils barely started in construction, or when they are little more than crushed rock, mobilize so little of the materials in the absence of clay that forest trees and other woody vegetation are all they can produce. There the organic matter produced is left on top of the soil. Soils farther along in the construction process under higher rainfall, but with insignificant soil leaching, build humus within the soil by means of leguminous, herbaceous growths. These latter soil improvements are possibly only on calcium-laden soils. Here also nitrogen is captured from the atmosphere to contribute its special humus compounds of blacker color that make choice soils. This special humus of narrower carbon-nitrogen ratio moves its nitrogen downward readily; gives a fine, stable, granular structure to the soil; and develops those prairie soils of deep, dark profiles on which the production of food and feed of high quality is so universally recognized.

Under still higher rainfalls to leach soils more toward their destruction, the acid dominance and fertility deficiency encourage a carbonaceous vegetation rather than a proteinaceous one. Humus made from this material has a wide carbon-nitrogen ratio. Consequently, nitrogen is hoarded near the soil surface by microbial competition for it. This magnifies the differences in color and makes more prominent the surface and subsoil horizons in the profile. While the leaching forces are pulling nutrient elements downward, plant roots and struggles by surviving vegetation are pulling them upward to magnify the contrasting darker color and higher fertility in the surface layer against the fertility deficiency in the lighter colored subsoil. This second soil horizon becomes a kind of a "No man's land" over which both forces have fought for the



Climatic and vegetational soil groups of the United States. (*After Marbut* 1935.)

nutrient elements, leaving little of fertility value for crop production after the surface soil is eroded. *Humus, by its prominence and scarcity in different degrees; its distribution in the profile in different extents; its different carbon-nitrogen ratio; and its differing speeds of nitrogen mobilization during the growing season, is associated with the mobilized soil fertility and the crop-producing power of high value as nutrition to higher forms of life.*

Climatic Geography Locates Mainly Carbonaceous or Proteinaceous Crops According to the Requisite Soil Fertility

Differences in climate are basic to differences in the degree of soil development and therefore to differences in the degree to which the soil provides the elements of plant nutrition. Too readily have we accepted the belief that the chemical composition of plants is controlled by the differences in rainfall rather than by the differences in soil fertility brought about by those differences in precipitation. Too readily have we accepted the belief that a single variety of plant is always of the same composition and that it delivers seeds or fruits of constant nutritive value. So-called "hard" wheat is grown in regions of lower annual rainfall. Its higher protein content, which is responsible for the "hardness" and better properties for so-called "light" bread, originates, however, only on soils still well supplied with calcium, and hence with other fertilizer elements, whereby a good supply of nitrogen is properly mobilized to make the protein production possible. Similarly "soft" wheat is ascribed to higher rainfall areas. Yet by providing the proper soil fertility, the wheat in the so-called "soft" wheat areas can be made as "hard" as any ever grown in the drier, hard wheat regions.

Starchiness of the wheat results from the process of photosynthesis within the leaves of the plants. Starch represents the carbon taken from the atmosphere and the water drawn up from the soil and both fabricated into this carbohydrate form by sunshine power in the chlorophyllous part of the leaf. It is an animal or human food having only energy value. Other carbohydrates, including cellulose, fiber, lignin, and less digestible forms represent plant bulk that increases rapidly with increasing dependence on constituents obtained from water, air, and sunshine. Plant bulk, or the size of the plant factory for fabricating products of weather origin, is rapidly increased with the advancing season of growth. This carbohydrate production or the increase in plant bulk is therefore closely related to the weather.

Figure 2.—Rainfall is the natural force weathering rock to soil. Exclusive of the western coast of the United States there is an increasing amount of rainfall from west to east and southeast to serve in soil construction in the western half and in soil destruction in the eastern half (upper figure).

When rainfall is divided by evaporation from free water surface (both as inches/acre/year times 100, or as percentage) the high evaporation in the cornbelt to lessen the leaching effect of the rain, it is readily understandable why the cornbelt was "prairie" soils (middle figure).

The weathering agencies as climatic forces of the United States serve clearly to give us the soil areas as they were mapped, with soils "in construction" in the western half, and soils "in destruction" in the eastern half, and the properties of the soils as they minister for or against particular crop production (lower figure).

The production of protein within the plant, or of the many other essentials for body construction and bone-building in humans and animals, is, however, more than a matter of weather. This process represents the mobilization of the soil fertility through the plant factory. The output in the form of these compounds as bulk is not so large. The amounts of these essentials within the crop are not so readily represented by the bulk of vegetative mass. Rather, their elaboration within the plant during the entire growing season may result in only the small amount finally delivered as the seed crop. It is these complex elaborations, however, that have high value as foods in terms of body building rather than in terms of provisioning it with fuels. They come only from the soil fertility. In consequence, they are apt to be deficient in the plant's crop delivery because of our failing soils.

Proteinaceousness of the crop is connected with soils that are less leached of their calcium and other elements of soil fertility. Only the more fertile soils can therefore give us, in abundance, the feeds and foods so essential for growing young animals with good bone and good brawn. Soils in regions of lower rainfall, then, provide the soil fertility to serve this function. On the other hand, the carbonaceous crops are readily produced on soils more highly leached and of lower content in soil fertility. Such soils still supply the potassium requisite for carbohydrates synthesis but they are deficient in the calcium, the phosphorus, the nitrogen, and other requisites by which these carbonaceous compounds of energy values can be converted through biosynthesis into proteins, vitamins, and other complexes serving in body construction rather than as energy for keeping it going or maintaining its temperature.

Figure 3.—The native vegetation of Kansas increases in tonnage production per acre from west to east as the rainfall increases from 17 to 37 inches. Its chemical composition is related to the fertility of the soil, as indicated by the bison's choice of buffalo grass because of its nutritive value more than its tonnage yield per acre.

The climatic geography of the United States and its crop distribution serve very effectively to illustrate this general principle of soil fertility depletion as basic to the natural incidence, or to the success on their introduction, of carbonaceous or woody crops in contrast to the more fertile and less leached soils as natural areas for proteinaceous products. In the rainfall of the United States (exclusive of the western coast) the lowest annual precipitation is in the West with less than ten inches. As

one goes eastward. there are longitudinal zones of increasing amounts until one reaches the belt of 30 to 40 inches of rainfall. This amount runs north and south in the southern half as a longitudinal belt but more like a blanket over the northern portion of the eastern half of our country. In the southeastern states the annual rainfall figures are not so zonally arranged as they climb to the serious soil-leaching amounts of 50 to 60 inches per annum.

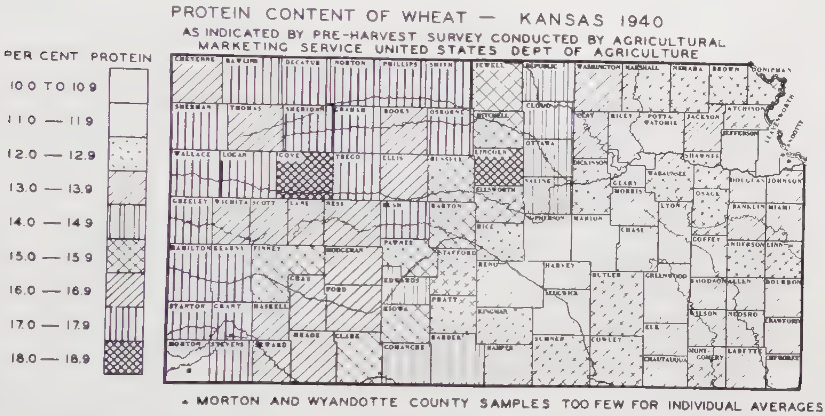


Figure 4.—Protein production demands more than air and water. The elaboration of this food complex depends on soil fertility. As the soils are less leached by lower rainfall the wheat grain is higher in protein. Using the lower tier of counties in Kansas going from the East (37 inches rainfall) to the West (17 inches rainfall), the protein content of the wheat in 1940 went from 10 to 17 per cent.

In terms of this picture of the precipitation one can see that the rainfall increase up to about 30 inches is an ascending force in soil construction. Beyond this figure, and particularly as one goes southeastward to higher temperature, one can see the increased rainfall as a force in soil destruction. Fortunately for the area known as "the cornbelt", its location so far from seashore and within the center of a large land mass conferring the properties collectively known as "continentality", gives it a higher summer evaporation which reduces the leaching of the nutrients by its higher rainfall. Its soils have therefore retained significant amounts of those mineral reserves representing the plant nutrients in the original rocks. The low ratios of the annual rainfall to annual evaporation from a free water surface as they can be delineated on the map serve to show that the fertility of the cornbelt is similar to that of the grassy prairie areas farther west. It was the fertility of the soil that presented the cornbelt pioneers with the highly productive plains of the prairies. It was not the prairie grasses that made the fertile soils, as one might erroneously be led to believe. Conversely, the fertile soils made the nutritious grass.

Unfortunately for Florida and the southeastern part of the United States, this is an area of high rainfall. This weathering agent has not only depleted the soil of its nutritive mineral reserves common in the silt and sand, but has also given a clay that in its chemical makeup is

different from clay under lower rainfall and temperature. In addition, the clay is lower in its exchange capacity and therefore in its ability to serve as a jobber. It can take less out of solution of fertilizers and can therefore give less to crops growing on it. Then, too, with soils formed from marine deposits or marine-worked materials it is not surprising that soils should be segregations and made up mainly of peat deposits in one area, sand or silt deposits in another, and not of the well blended combinations of sand, silt, and clay serving more uniformly for crop production. In the region of southeastern United States, then, the climatic forces in soil construction and soil destruction stand out prominently as the agriculture, modified accordingly, so forcefully testifies.

The Soil Fertility Pattern of the United States Is Replicated in Other Centers of Civilization in the World

Here is a pattern of soil conditions, as determined by climatic forces, by which we can locate areas of similar soil productivity on the globe. Within the temperate zone these areas with annual rainfalls approaching the 30-inch figure, represent the combination of conditions that gave us soils which provision life with its food essentials. It was in this narrow belt of soils running north and south across the United States that the pioneer found the buffalo roaming in thundering herds. It is on these same soils that the cattle production is centered today with possible shipment eastward to higher rainfall areas for fattening purposes. It is on this belt that wheat as the staff of life can be produced. But even this food grain demonstrates its high protein content of eighteen per cent in the 17-inch rainfall area of western Kansas in contrast to the ten per cent of protein in wheat grown in eastern Kansas with its 37 inches of annual rainfall. It is this fortunate combination of climatic forces operating on a fortunate combination of mineral resources originally left to the climate for construction of soil that makes the midlands of the United States the well-laden breadbasket and meat basket that it is.

It is on similar soil patterns that other parts of the world are supporting corresponding populations and have established civilizations of similar accomplishments. That hard wheat has been the staff of life so universally the world over is not wholly due to inborn powers in the crop. Rather it is the soil fertility by which this crop can be both a protein-producer of growth values and a starch-former of energy values that locates civilizations on the higher rainfall sides of the hard wheat belts of the world. It is this soil fertility condition that is closely linked with all civilizations, not only in the United States but in other parts of the globe. A close scrutiny of the world for similar climatic soil combinations demonstrates that wherever civilizations of higher accomplishments have been established they are built on such soils of similar fertility levels serving as their basic resource. Europe with its hard wheat belt in Russia and higher rainfalls to the west is the picture of the United States with its East and West reversed. Similar soil and climatic combinations prevail in the Argentine, South Africa, Australia, New Zealand and to a similar degree in northeastern China. Studied in terms of the world wars, the basic food resources at the disposal of the warring nations loom as factors in the combat as well as any military or political maneuverings.

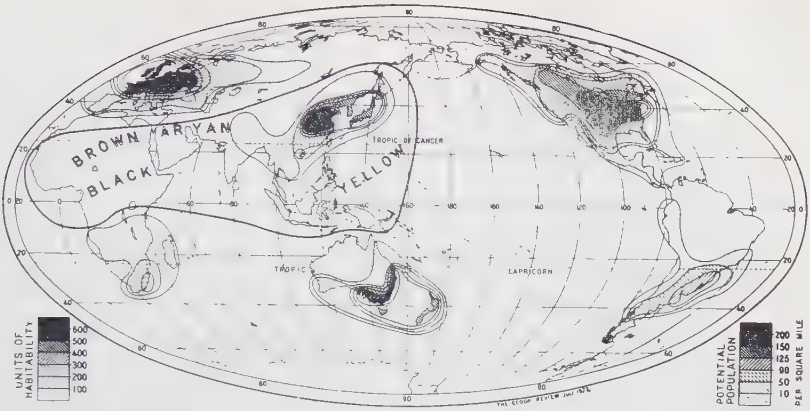


Figure 5.—The settlements of peoples in different parts of the world suggest the higher concentrations of them according as the climatic forces have made soils of such fertility levels that guarantee survival and permit development of their civilizations. (Map according to Griffith Taylor.)

Plant Ecology Indicates the Vegetations Changing in Chemical Composition with the Declining Soil Fertility

The distribution of plants across the United States reveals a pattern of their chemical composition in terms of service as animal and human foods as well as of an organized array of plant varieties. The higher concentration of fertility in the less leached soils gives a prairie grass vegetation. Among these plants are the many proteinaceous, mineral-rich legumes growing naturally to stock the soils with nitrogen and humus by which the more proteinaceous and more mineral-rich non-legumes as well as legumes can flourish. These blacker soils, with a relative dominance of calcium over potassium within them and therefore a corresponding dominance of protein synthesis in plant functions, produce a physiological basis for the fine bone and big brawn of the buffalo, native there.

Forests abound where quite the opposite fertility condition prevails, or where potassium is in relative dominance to calcium. This is the situation in rocky regions not yet developed into soils, also on highly weathered soils from the clay of which sufficient potassium is still delivered to the deeply penetrating tree roots to support this plant's activities that are predominantly photosynthetic as it builds its body mainly of wood. Even this carbonaceous construction mainly by means of air, water, and sunshine—all supra-soil in origin and action—can proceed only as the annual drop of fertility elements in the leaves keeps going back to maintain this annual cycle of self-fertilization. *The plant pattern is as the soil permits and not as the plant wills.*

The processes of soil development and soil depletion then give us the ecological pattern of plant composition and therefore the pattern also of the possibilities of feeding wild animal life, domestic animal life, and human life as well. They point the warning finger to the waning of human health, too, when cropping depletes the soil and when the same

crop, that once was a life-sustaining food with body-building powers, has shifted its chemical output to products that are neither proteinaceous nor mineral-rich as they once were, but have become carbonaceous or woody materials of fuel value only. Our depletion of the soil or our failure to restore the removed nutrients is therefore an insidious underminer of health in its many ramifications. As our soils are becoming deficient through our exhaustion of them, or as they had serious natural deficiencies originally, our foods have been or are becoming deficient and our health and growth along with them. And, unfortunately, the popular demand is for cures for these troubles, not for prevention by way of more fertility put back to give us restored soils.

Animal Instincts Offer Helpful Suggestions

Careful observations of the behavior of wild animals in their selection of herbages on different soils and of domestic animals according to soils differently treated will give optimism to our efforts in soil improvement for better foods and hence for health's sake. It is a common observation that in the spring of the year cattle break out on to the highway and railroad right-of-ways. Little have we reminded ourselves that they will face possible body injury while going through the fence in order to get the more nutritious grass growing where the soil has not been so highly depleted of its fertility by excessive crop removal. Much has been said about keeping cows at home by means of better fences to avoid loss of valuable meat animals in highway or railway casualties. More might well be said about making the pasture soils as fertile and as productive of nutritious forages as the highway soils. We would thereby avoid the need for excessive fencing when the quality of the feed on the farm tempts the cow more than does that of the grazing on the highway. Soil treatments can be tested against the animal choices to indicate the better feeding values in the crop. Animal assays of the crop can be guides for the proper soil treatment by which our soils, seemingly threatening danger to our health as well as to that of our animals, can give us better qualities of feed and food.

The deer has demonstrated by its choice of browse in the forest that even trees give different chemical compositions in their growing buds and different feeds to wild animals. Sheep have selected the early growing rye where manure from alfalfa was applied, and in the same field where the soil was enriched by lime. Cattle have chosen pastures fertilized with 200 pounds of fertilizer in preference to that with only 100 pounds of this soil treatment. Hogs have taken the grain from the part of the field first where the soil was once fertilized to grow alfalfa. They have taken the corn at different rates from different compartments of the self-feeder according to the treatments of the soil where the grain was grown. The choices of the rats in cutting the bags of the same stored grains corresponded with the choice by the hogs. The rats failed to cut the bags of the corn that was disregarded by the hogs.

These animal choices are in accord with the demonstrations by Dr. Curt Richter using experimental rats to demonstrate their appetite as an attempt to maintain their physiological condition at the proper level for their best nourishment and survival. We are just beginning to appreciate

Figure 6.—Hogs put into this field to "hog down" the corn selected this area of the forty acres where this Missouri farmer had treated the soil and grown alfalfa some years previously. It was Prof. Evvard, the inventor of the self-feeder, who said, "If you will give the pig a chance it will make a hog of itself in less time than you will."

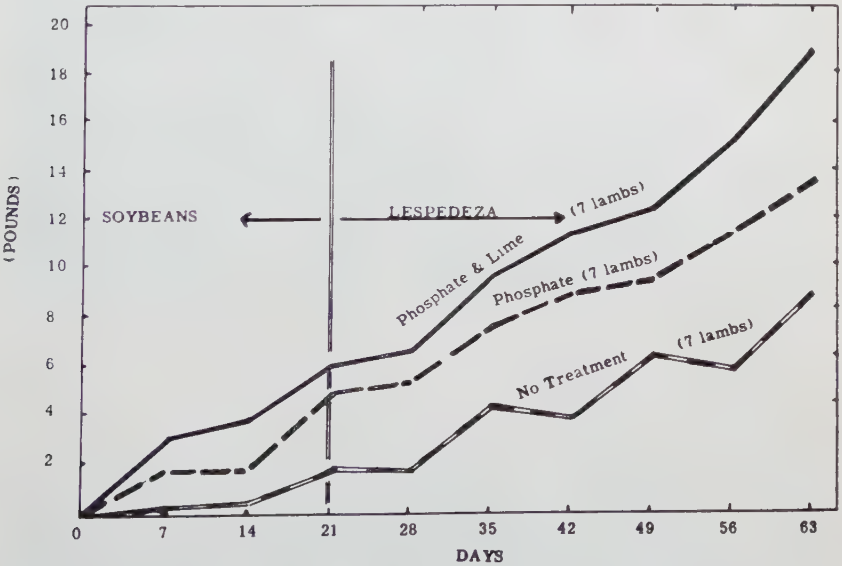


Figure 7.—Three lots of lambs were fed for nine weeks on equal amounts of grains and of hays from adjoining plots given the different soil treatments. Those fed with hay from the plots given lime and phosphate gained twice as much as those fed from the hays grown without soil treatment.

the fine discrimination exercised by animals with reference to the chemical composition of their feeds as these feed qualities are dependent on the fertility of the soils producing them.

Diseases of domestic animals suggest that in their confinement by fences and barns to feeds provided for them, the animals are merely making manifest our failure to nourish them properly. Rickets, "loin disease", "creeps", acetonemia, pregnancy disease, and other ailments forcefully suggest that we need to look to the quality "grown into" the feed rather than antidotes or remedies "thrown into" it and into the animals.

Experiments Demonstrate Improved Feed Quality Through Fertilization of the Soil

Experiments using the animals to assay the value of the soil treatment in producing better feed quality have demonstrated the validity of the belief that we can feed our animals by treating the soil. The use of equal amounts of supplements and of hay per head per day with the hay coming from three plots with different soil treatments demonstrated clearly that the animals' meat-making machine can run no more efficiently than is made possible by the raw materials supplied as feed.

Figure 8.—Fertilizer treatments of the soil register their beneficial effects in the plant, but more noticeably in the physiology of the animal, as indicated by better weight, wool, fur, bones, or other body products and functions. On the left, the rabbit and bones record the lack of soil treatment, in contrast to the effect of treatment measured by similar gauges on the right.

Three soil treatments were used in growing the hay, namely (a) no treatment, (b) superphosphate, and (c) lime and superphosphate. The gains—as pounds per head—during sixty-three days corresponding to these treatments were 8, 14, and 18, respectively. By giving attention to the soil, the meat output by the animal from the same bulk of feed and during the same time was more than doubled where lime and phosphate were the fertilizers for the soybean and the lespedeza hays. The soil treatments doubled the feed efficiency or the animal's efficiency in making meat.

Rabbits selected for uniformity in sexes and weights as litter mates, were fed the lespedeza hay grown on the five different soil types of the experiment fields in five different parts of Missouri both with and without soil treatment, only to find that the animals on hays from untreated soils in final appearances suggested five distinctly different kinds of rabbits. Those fed the hay from treated soils were similar. Studies of their various body parts, as glands, bones, and others, revealed the extensive variations as the result of the differences, not in initial animal, not in kind of plant, but in the quality of the same feed originating in the differences in the fertility of the soil growing it. Differences in the soils made differences when the animals were originally alike in age, size, pedigree and other properties of controlled uniformity at the outset. They were eventually different because the soils supporting them were different and therefore the qualities of their forage feeds were different.

Figure 9.—Human, as well as plant and animal health, declines as the fertility of of our soils is leached or washed away.

Human skeletal parts are well hidden away and are not subject to measurements of size, breaking strength or chemical composition. Teeth are, however, an exposed skeletal part. By their failures to develop properly or to maintain themselves permanently, they reflect the deficient body physiology. Other body weaknesses are also well hidden so that most body organs can be defective or failing almost fifty per cent before the body's buffer capacity can no longer keep the deficiency hidden. Defective body parts represent deficiencies in the means of constructing them. They speak for failure in body-building foods more than for shortages in energy foods. They suggest the possibility of foods lower in quality as growth promotors than expected. These changed qualities

may be the difference within the same plant species due to changes in the level of the soil fertility growing it.

Declining soil fertility, then, as it provokes the plant's failing synthesis of growth essentials may be the fundamental cause in the declining food quality. These qualities cannot be adequately bolstered by mineral additions to the ration. If these are the facts, then, we may well look to the treatment of our soils with those fertilizer essentials that contribute to plant composition in terms of the elaborated compounds that give food its life sustaining values of the highest service in terms of good health. In this respect all of us, and our children need to appreciate the great fact, that food quality for all life is no higher than the fertility of the soil producing it. If our declining soil fertility is not to sweep us down with it, our efforts in soil conservation must be to push the fertility of the soil back up by a proper treatment of the land. Our future health as well as our wealth depends on the restoration of our soils.

MAGNETISM IN THE MINOR ELEMENTS—THE UNIQUENESS OF COPPER IN CERTAIN ENZYME REACTIONS

Oskar Baudisch *

INTRODUCTION

As far back as 1893 the "oligodynamic action" of copper was described by Nägeli(1). The first paper concerning enzyme action and copper came from H. Bortels.(2) who was of the opinion that copper might play an active part in phenoloxidases. Harrison and Subrahmanya(3) demonstrated that copper accelerates growth of rice and received with $CuSO_4$ in concentration from 1 : 10000 to 1 : 20000 growth promotion of more than 20 per cent. L. Hiltner(4) found that peas grown in water cultures grow exceedingly better with the distilled water made in an apparatus made of copper instead of glass. McHargue(5) in a paper titled: "Occurrence of copper, manganese, zinc, nickel and cobalt in soils, plants and animals and their possible function as vital factors" (1925) comes to the conclusion that copper has a biological function in the living cell.

From the viewpoint of agricultural chemistry the most important development in the use of copper in plant growth was obtained by the intensive studies for the prevention of the so-called (in England) "Heath bog disease" or "yellowtip" which is prevalent in marshy soils.

J. Hudig, C. Meijer, and J. Goodyk(6) in 1927 found that the addition of small amounts of copper to the marshy soils is helpful in preventing the "heath bog disease, or reclamation disease." More enlightening research in this field was carried by men like Brüne(7), Büttner(8), Tacke(9), Freckmann(10), and Wangenheim(11).

The question naturally arises whether copper in preventing the heath bog disease is unique or if other metals of the transition group under similar circumstances can replace copper? Pioneer work concerning this important question was carried out by Allison, Bryan and Hunter(12), in a paper titled "The stimulation of plant response on the raw peat soils of the Florida Everglades through the use of copper sulfate and other chemicals," published in 1927. They found that copper is the most potent of the metals of the transition group. In 1928 Jörgensen(13) confirmed the results of former investigators that copper sulfate, as it was to be assumed, does not influence the microorganisms of the soil but that the copper ions are solely responsible for the beneficial effect in copper sulfate treated marshy soils. Slowly it became currently accepted that a deficiency of copper in marshy soils or in peat was to be blamed for the heath bog disease and for the poor growth of plants on such soil. The addition of copper to the soils was an effective remedy, often with miraculous results. In 1933 von Brandenburg(14) proved conclusively on oats with water cultures that deficiency of copper brings about all

* Director, Research Division, Saratoga Springs Commission, Saratoga Springs, New York.

the symptoms of the "bog disease" usually observed in the open marsh lands.

It is of interest to note that Tacke and also Freckmann have found a correlation between resistance of certain plants to frost and copper. Small amounts of copper sulfate are a protection against frost. In this connection the observation is of importance, which was made by the writer many years ago, that the amount of polyphenol compounds in green plants rises considerably during cold spells or frost. Alpine plants at high altitude, which are subjected to extreme cold, contain tannin compounds in large amounts. Since copper is the prosthetic group for various phenol oxidases, the combination with copper may lead to an effective remedy against frost damage of vegetable culture. Very important is another observation by Allison and Hunter (15 and 16). In their experiments with copper, manganese and zinc in the agricultural development of the low moor soils of the Florida Everglades they found that zinc is assisting conspicuously the great benefit brought about by copper, especially under conditions of prompt planting of the crop (peanuts) following the copper treatment on raw soil.

In a publication Forsee (17) emphasizes how the minor element question in Florida is undoubtedly of outstanding importance and demonstrates this statement by excellent experimental evidence under greenhouse conditions. The addition of the minor element copper to Everglades peat is necessary for the normal growth of a great variety of agricultural plants and in most cases determines the difference between a good yield and complete crop failure. The importance of copper sulfate as a soil amendment on Everglades peat cannot be over-emphasized and its economical value to growers in that area is inestimable. Copper deficiency in soils and plants delays mainly the generative development but also brings about leaf necrosis, chlorophyl defects and other symptoms of deficiency diseases, Allison *et al* (12, 15 and 16).

COPPER AS A MINOR ELEMENT IN ENZYME CHEMISTRY

It is well known that copper reacts as a very potent oxidation catalyst for polyphenol and for phenylindiamin compounds—infinitesimal small amounts. Without copper the oxidation reaction stops altogether. What is the chemical nature or the mechanism of the different copper enzyme systems and how does copper exert and influence biological function? This is the question of primary interest in this paper and we shall try to elucidate the problem from the viewpoint of the chemist and physicist. We are seeking to find the answer for a real explanation of the atomic and molecular mechanism. Vitamins and minor elements, like cobalt, or copper, are functionally similar in certain respects, as both must be present in the living cell in the right amount in order to be beneficial. Their toxic effect lies often dangerously near to the beneficial healing effect concerning the amount of the metal in the living cell.

The question then arises, "what must we really investigate in order to find out the inherent force and functions of minor elements, and how can this difficult problem be approached?" It seems to the writer that the metal proteids are the keys with which we can enter this obscure realm of science and learn about the mysterious forces hidden in the metals

or elements. The fate of the living cell and its influence on the evolution of man seems to be borne out of the number and arrangements of electrons of each which forms a building stone element. Not 10 or 11 elements but 86 take part in the latest research work of life process according to Vernadsky. Still much greater is the number of isotopes which might be of equal importance in the biological factory of the living cell. Nothing is more obvious than the fact that the mineral supply of the soil and food are coupled with the evolution of man and influence his life conspicuously. The metals combine with the nitrogen of proteins and new compounds result with most specific chemical and physical characteristics for the metal as well as the added protein. On account of the metal combination the protein may change its structure and become highly active. All the nitrogen atoms of the protein molecule may become magnets and thus are able to draw other magnetic compounds in their field of force. Even if only *one* atom of copper combines with one nitrogen atom of the attached protein and converts this diamagnetic nitrogen into a paramagnetic one, thousands of nitrogen atoms of the crystal-like polypeptide chain structure may be affected and become somewhat activated. These polypeptide chains are now able to transfer wandering electrons and use them where they are of greatest need.

Conspicuous examples of the power of a metal after combination with protein are the heme compounds, especially hemoglobin and catalase. A few examples shall demonstrate this statement. One molecule of catalase, the most powerful enzyme known so far, decomposes 2,640 000 molecules of H_2O_2 per minute at 0° C. Catalase without iron is not reactive at all and iron without the organic catalase protein structure has only very feeble catalase action. According to Warburg (1938), it is the protein that primarily determines the specifity of the enzyme, the prosthetic group being less specific.

From the chemist's viewpoint it is highly interesting that in the heme compounds the iron ion is always boxed in a 16 membered porphin ring and linked to the 4 nitrogen atoms of 4 pyrrol rings. The porphin ring may react like a "Faraday cage". Ruben and coworker(18) assume that the highly symmetrical electrostatic field of the porphin ring is sufficiently strong to prevent any reversible equilibrium involving the central metal ion. It has been found that the 16 membered porphin ring can open on one place by oxidation processes. The iron ion in the opened rings is much less protected and can exchange with other elements like H, Cu, Ni, Co, or Zn easily. The iron, however, can also remain in the organic structure and become oxidized to Fe^{III}. The oxidation to trivalent iron changes decisively the chemical and physical properties of the heme compound. The iron is no longer able to bind molecular oxygen and the "flame of life" is extinguished.

The interchangeable binding and replacement of divalent iron in the porphin ring by other metals is very plausible and its biological significance should be studied by using radioactive isotopes. The magnetochemical study of heme compounds has revealed the amazing fact that the iron in hemoglobin, in spite of its bonding into the structure of the porphin ring, remains in ionic form and shows the magnetic susceptibility of ordinary Fe ions. For instance, the magnetic susceptibility of hemin equals 5 Bohr magnetons. (Fig. 1). Respiration, the most

important biological process is a magnetic reaction as Pauling has found. In order to build up the chemical basis of respiration, divalent iron is put in a framework (protoheme) with a protein (globin) to form a new compound (hemoglobin). The latter acts with molecular oxygen, which is a magnetic biradical, to form a reversible molecular compound. Its magnetic susceptibility is 5.46 Bohr magnetons per gram-atom of iron, which means that the iron is bonded ionically. Without iron there is no oxygen linked in the hemoglobin as the organic framework alone does not react with molecular oxygen.

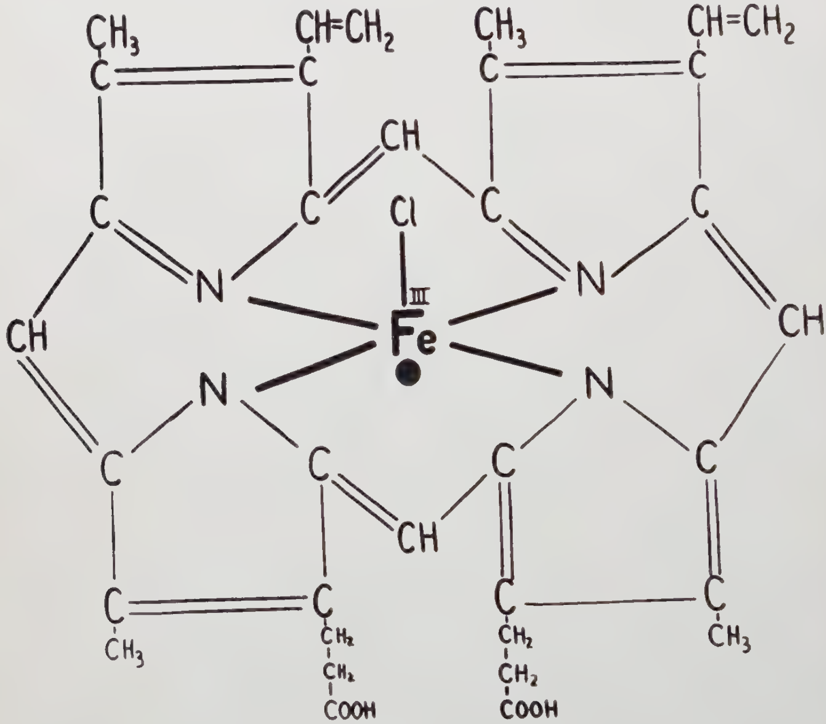


Figure 1.—Hemin.

The intensive experimental research on the heme compounds during the last twenty years has elucidated somewhat the question of what role the minor metals play in enzyme systems. In the heme compounds the iron ion is not combined directly with the protein but it is, as we said before, built into the 16 membered porphin ring. The reason for this is not yet altogether clear.

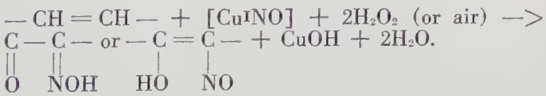
It is different with copper-containing enzyme systems, like ascorbic acid oxidase, polyphenol oxidase, laccase and hemocyanin. According to Kubowitz(19) in the case of polyphenol oxidases, copper is linked directly to the enzymatic protein. He has shown that these special enzymes are copper proteids, and by an ingenious arrangement, that copper is the prosthetic group of this enzyme. The copper enzyme was dialized

against a dilute solution of cyanide which trapped the copper; the enzyme inactivated by this procedure was immediately reactivated by small amounts of copper ions.

The heavy metals presumably act in most metal enzyme reactions as electron transfer systems, alternating between cuprous and cupric or ferrous and ferric states, but there are still other qualities developed in the combination of metals with organic substances which are of significance in life processes. The metal, like copper, on account of its electron structure, has characteristic properties. In order to find the basic principles of the biological action of trace or minor elements we have to study the electron shifts with modern tools and enter subatomic realms. In order to gain access to these subatomic realms we must first determine the types of bonding by which the metal is linked to the enzymatic system. From the type of bond which exists between the central metal atom and the atomic groupings, the magnetic properties of the central atom can be deduced, or *vice versa*. At the same time the characteristics and chemical structure of the attached organic groupings with which the trace element has formed a new complex are of importance. Since proteins are involved in enzymatic reactions, the problem of finding the details of the mechanism is difficult and complex. A simple chemical reaction must be found, in which copper reacts uniquely, or almost uniquely, and in which the attached atomic grouping is a simple inorganic or organic nitrogen compound. During such a reaction the characteristics of the simple metallic ion before and after binding, the nature of the added atoms, and the chemical and physical properties of the resulting molecule can be studied. It is decidedly important to find out the type of bonding that occurs between the metal and the attached groupings. For clarity, the names and symbols which are conventional in explaining the bondings, for instance between M and S, are as follows:

1. Electrovalence, $M^{\cdot} + S \longrightarrow M^{+}\ [S^{-}]$
2. Co-valence, $M^{\cdot} + {}^{\cdot}S \longrightarrow M : S$
3. Donor-acceptor valence, $M\!: + S \longrightarrow M\!: S$

In this paper the metal to be investigated is copper and the substance attached is NO. It will be seen later that in compounds all three kinds of bondings are to be found between certain metals and NO. In our example we have the simplest case of a copper-to-nitrogen attachment which also takes place in the attachment of copper to the enzymatic protein. The new reaction, called B reaction for brevity, in its simplest form can be expressed by the following scheme.



The writer has already published several articles on the B reaction (20), the mechanism of which remained rather obscure. A new simple procedure which makes the application of the B reaction very convenient has been found. If metallic copper is dissolved in an aqueous solution of hydroxylamine hydrochloride ($NH_2OH.HCl$) in the presence of air, a colorless clear liquid, L, is obtained which contains a cuprous salt of

nitrosyl ($Cu^{I}NO$). This combination is most reactive and can be used to add NOH to ethylene linkages. If for instance benzene is shaken at room temperature with solution L, some of the benzene is immediately converted into o-nitrosophenol (see Fig. 3, page 132). Since this compound with cupric ions gives a deep red water-soluble complex salt, the colorless solution L, on being shaken with benzene, becomes pink if the necessary oxidation is brought about by air, or intensely red if dilute H_2O_2 has been added to L. That solution L does attack benzene (toluene, xylene, etc.) quickly at room temperature is astonishing, and a closer study of the mechanism of the reaction is of general importance for enzyme chemistry, especially when copper alone is involved.

Let us first analyze why copper ions should differ from other ions of the transition elements. It has been found that in the B reaction only mercurous ions and silver ions can replace copper, but they are much less effective, and nothing more will be said about these elements in this paper. We shall, however, analyze the properties of copper and of the attached NO in greater detail from the viewpoint of magneto-chemistry.

In regard to the magnetic properties of copper ions, it is known that cuprous ions (18 electrons) are diamagnetic. It has, however, been found that a feeble paramagnetism is present(21), a fact which seems to be of significance in the linkage of NO to cuprous ions. Cupric ions (17 electrons) possess the paramagnetism of about 1.73 Bohr magnetons. There is no other metallic ion in which the difference in magnetism of the two valence states of the simple (not complex) ions is so conspicuous as in the copper ions Cu^{I} and Cu^{II}. Cuprous ions are practically diamagnetic, while cupric ions are paramagnetic. Another difference between copper ions is that cuprous ions usually have a greater tendency to form an octahedral arrangement in space, while cupric ions possess a square or tetrahedral structure. For instance, the Cu^{+} ion links 6 molecules of pyridine, while the Cu^{++} ion links only 4. In regard to the change in valence of copper ions,

$$Cu^{+} \underset{}{\overset{\pm e}{\rightleftharpoons}} Cu^{++}$$

it is significant that this change takes place easily in weakly acid solution with an oxidation potential of a low voltage. The oxidation potential for the release of an electron from the cations of other transition elements is far too high to occur in acid solutions.

	Oxidation potential
$Mn^{++} \longrightarrow Mn^{+++}$	1.5 volt
$Ni^{++} \longrightarrow Ni^{+++}$	very high
$Co^{++} \longrightarrow Co^{+++}$	1.8 volt
$Fe^{++} \longrightarrow Fe^{+++}$	0.75 volt
$Cu^{+} \longrightarrow Cu^{++}$	0.2 volt

However, the oxidation potential can be altered by the formation of complex coordinated ions. The addition of nitrogen compounds lowers the potential of copper ions and makes the valence shift still more easily in acid solutions.

Another peculiarity of copper ions which distinguishes them from ions of the other transition elements is the fact that attached atom group-

ings or negative ionic groups in the *second* sphere in the Werner complex influence the coordination number of the atoms or molecules linked in the first sphere.

From these few examples it can be seen that the chemical and physical characteristics of copper ions differ conspicuously from those of simple ions of other elements of the transition group.

We now have to study what happens with the copper ion if it combines with a nitrogen atom especially with a nitrogen atom of a protein or polypeptide molecule. We could by this research perhaps elucidate the enzyme chemistry and even solve the puzzle of the protein structure after combining with a metal of the transition group. The protein structure is, however, much too complicated and we have to content ourselves with the study of the nitrogen of nitric oxide, NO, with copper. In the last analysis nitrogen in NO and nitrogen in protein are the same element. From the viewpoint of chemical evolution we can demonstrate the relation between NO and the chief protein linkage which forms the "backbone" $-\mathrm{H}-\underset{\mathrm{OH}}{\mathrm{C}}=\mathrm{N}$ or $-\underset{\overset{\|}{\mathrm{O}}}{\mathrm{C}}-\mathrm{NH}-$ of the protein molecule.

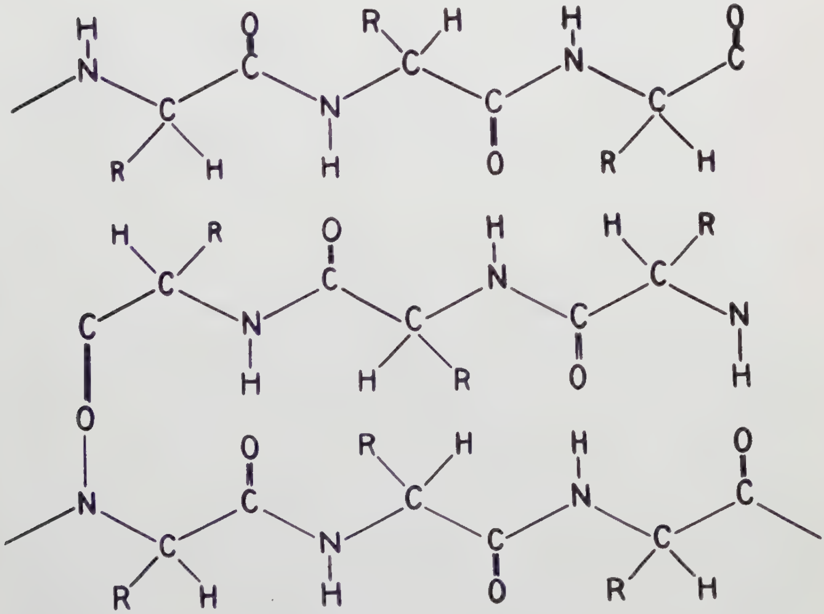


Figure 2.—Structure of Protein.

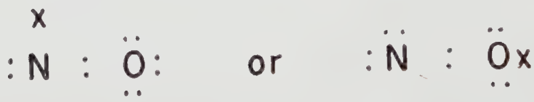
Nitric oxide has in recent years become of biological interest also from another angle. The discovery that N_2O_5, NO, N_2O, are constituents of the ozone layer of the stratosphere is of great significance. Very small amounts of NO are omnipresent in the atmosphere (0.01 to 2 p.p.m.). Only in recent years have the peculiarities of the NO molecule been fully understood. It is necessary to present a few data for our investigation:

NO with its 11 electrons is a paramagnetic gas. It has a great affinity for metals and metallic ions; for instance, the following elements bind NO and form nitrosyl compounds.

Mn	Fe	Co	Ni	Cu	Zn
	Ru	Rh	Pd		
	Os			Cd	

In the resulting nitrosyl or nitroso metal compounds the type of bonding is very different with the various metallic ions, and thus the chemical and physical behavior of the attached NO differs. The valence conditions of the metallic ions are of decisive importance. Both cuprous and cupric ions bind NO. The nature of the bond, however, is entirely different, and the mechanism of the B reaction is based on this difference in bonding of NO to copper ions and of the changes in valence: cuprous cupric in an acid medium.

The electronic arrangement in NO is expressed by the following scheme:



Either the nitrogen or the oxygen atom can have the free spinning electron (x). NO has 3 electrons available for combination with other substances. Sometimes it uses all 3, sometimes only 2, and it can further react as a positive ion NO^+ which possesses only 10 electrons and thus is isosteric with CO. In this case the positive NO ion involves an oxidation:

In nitroprusside compounds the NO has been exodized.
The central iron atom is divalent. All the ferrous pentacyano compounds, as Welo and the writer found many years ago (22 and 23), are diamagnetic.

The NO in nitroprussides is more reactive, because it does not possess free spinning electrons. Some examples showing how NO reacts with different metals, using its 3 electrons in different ways, follows:

In the compound $\left[Co(CO)_3\right]^{NO}$ the NO donates 3 electrons to the cobalt atom (24) and according to the Welo and Baudisch rule (23), the compound is diamagnetic. It has a krypton structure ($27 + 3 + 3 \times 2 = 66$). There are, however, metal nitroso complexes which are paramagnetic. If the electron shell of the reacting ions (with the minimum valence for the starting phase) has an even number of electrons, then the linkage of 1 NO molecule leads to a paramagnetic complex, the addition of 2 NO molecules to a diamagnetic complex. The cuprous ion complexes with NO have recently been studied magnetically by R. Asmussen (25). CuCl is diamagnetic and so is NOCl. When combined, a paramagnetic compound with monovalent copper is formed, $[Cu(NO)]Cl_2$. Magnetic measurements prove that the NO has 1 unbound electron which represents the magnetic susceptibility of 1 Bohr magneton. NO is so loosely bound

in the Asmussen complex that it can be driven out by CO_2 gas. Similar conditions were found when powdered copper metal was dissolved in an aqueous solution of $NH_2OH.HCl$. The simplest way to carry out the B reaction successfully is described. By the following procedure a cuprous nitroso compound in which the nitroso group is loosely linked and is converted easily into nitrosyl. NOH, depending on a hydrating or dehydrating medium, is formed

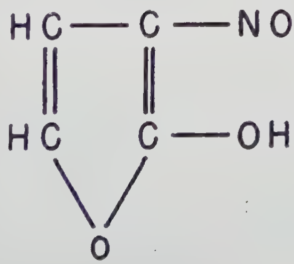
$$[CuNO]Cl \underset{-H}{\overset{+H}{\rightleftharpoons}} CuCl + NOH$$

The liquid L can be used with success to demonstrate the B reaction. This is an excellent reaction to demonstrate how easily benzene is attacked at room temperature and two groups, NO and OH, are substituted in the ring.

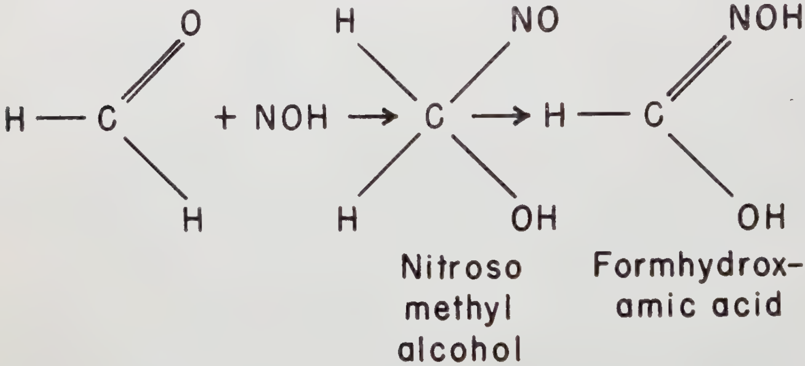
1 part of the clear liquid L is shaken with excess benzene or with pure ligroin which contains very small amounts of benzene. After the mixture is shaken for some time, a dilute H_2O_2 solution is added. The color of the aqueous layer almost immediately becomes intense red and the red deepens on further standing or shaking. O-Nitrosophenol copper which is soluble in water, with a deep red color, is formed. If the reaction should fail to occur immediately, the addition of small amounts of borax or guanidine will help to adjust the pH (4 to 6). Dilute aqueous pyridine and $CHCl_3$ are added to the red mixture in order to produce free o-nitrosophenol. The red copper salt is taken up by chloroform when shaken. Wash the separated chloroform layer with ice water several times and add dilute $KHSO_4$ solution or dilute H_2SO_4. The red $CHCl_3$ becomes a beautiful green, and free o-nitrosophenol is formed. It can be converted to the red calcium salt by shaking with $Ca(OH)_2$ and kept in the refrigerator under pure ligroin for use in chemical analyses.

The copper nitroso compound present in the freshly prepared colorless liquid L can be extracted easily with organic solvents such as benzene, toluene, ethyl acetate, and others. In the absence of air this extract is and remains colorless. It autoxidizes quickly in contact with air, and brown CuOH or other basic cuprous compounds are formed, while in the air above volatile NO can be recognized with filter paper strips dipped into Griess's reagent. On longer standing in contact with air all the copper precipitates out from the organic solvent in the form of a yellowish brown precipitate and the reactivity of the L solution is entirely lost.

The B reaction can be applied not only to aromatic hydrocarbons but many other ring compounds containing the ethylene grouping. The writer has found that furan is converted in small amounts to 3-nitroso-2-hydroxyfuran



if furan is shaken at room temperature with solution L. The new nitroso compound shows the same basic color with metallic ions as o-nitrosophenol. It is of significance that, in any aromatic compound in which ethylene groupings are inserted, the —CH=CH— groupings react spontaneously with the L solution, and, in the presence of air or H_2O_2, o-nitrosohydroxy compounds are formed. The B reaction takes place only in an acid medium, and the best pH is usually from 2 to 6. The substitution of acid groups in the benzene nucleus has, however, a great influence on the shift of the pH to the acid side and on the stability of the metal complexes with the resulting o-nitrosophenols, making them more stable on the acid side. The nitrosyl reaction with Angeli salt or with Piloty's acid has always been carried out in a weakly alkaline medium. The writer, in conjunction with Coert(26), has first shown that the free NOH in neutral solution reacts usually as NO + H. For instance, *formaldehyde* and NOH give blue-green nitrosomethyl alcohol which is quickly rearranged to colorless formhydroxamic acid.



We have prepared about 70 new o-nitrosophenol compounds and tested them for complex formation with metallic ions. In another paper, Dr. G. Cronheim will describe these new compounds.

In regard to the mechanism of the B reaction, it is to be assumed that the benzene reacts with the [Cu(NO)] radical in the following manner:

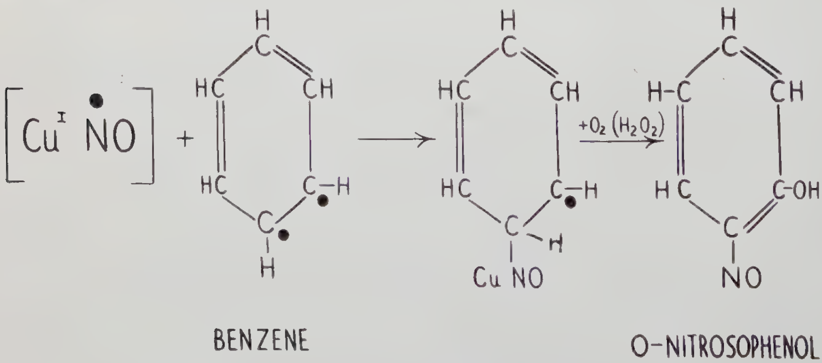


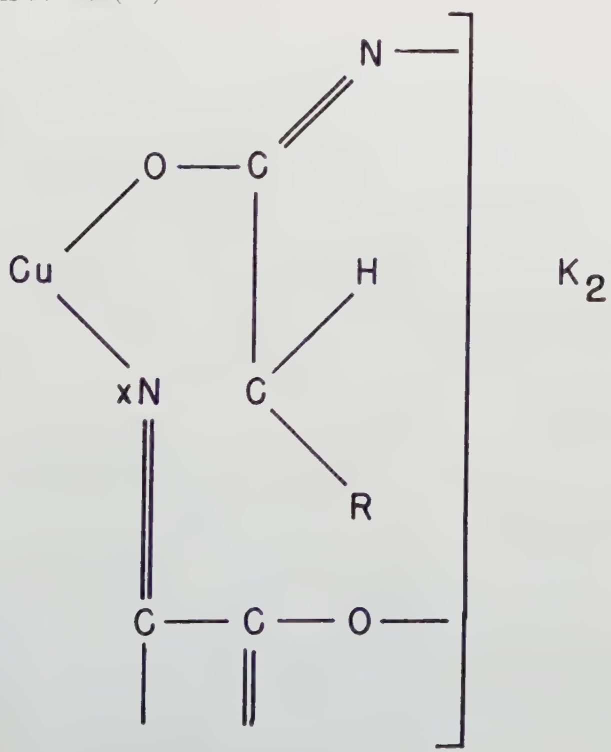
Figure 3.—Magnetic Coupling of Nitrogen with Carbon.

The labile intermediate compound becomes oxidized to o-nitrosophenol by air or oxygen or by H_2O_2.

The ready change in the valence of copper ions in acid solutions is another feature of the mechanism of the B reaction. In addition to the radical reaction with radicals such as [Cu(NO)], NO, and H, it must be taken into consideration that a chain reaction takes place, and the radicals mentioned are members of the chain. Speculation concerning the mechanism of the actual chain reaction cannot be made at the present time, but further experimental work should reveal more facts and elucidate the mechanism of the B reaction still further.

The knowledge gained by studying the mechanism of the B reaction shall now be used in a discussion of the polyphenol oxidases in which copper is unique.

It is to be assumed that certain metals linked to polypeptides bring about a rearrangement of the molecular structure and, in general, activate the polypeptide molecules. For instance, in the formula below, the nitrogen atoms become magnets on account of uncompensated electrons and so acquire radical character. In such cases, we speak of resonance or electron isomerism. The enzyme action possibly occurs in a manner parallel to the formation of the stabilized free radical brought about by the donor-acceptor binding of copper ions. In this action we must seek the foremost value and importance of trace elements. If, for instance, copper reacts with a polypeptide, a compound of the following graphic structure is formed(27).



In this structure the nitrogen (N_x) linked to copper possesses an uncompensated electron or a micromagnetic field (Bohr magneton). Radicals in combination with metal ions or metal complex ions seem to be of fundamental importance in biological synthesis. It is important, furthermore, that a metal ion, like copper, which had already linked nitrogen-containing molecules and formed a Werner complex on account of such linkage receive selective affinity for other atoms, molecules, or groups. The copper atom, like other central metal atoms, has the tendency to complete or saturate its uncompensated coordination position by either donator or acceptor electrons.

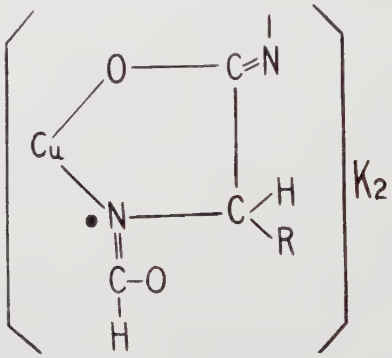


Figure 4.—Copper Peptide Complex.

In general we have to assume that nitrogen of the protein is linked to copper by magnetic coupling. After combination has taken place the nitrogen atoms of the polypeptide chains are probably in an "excited" stage and become very reactive by their magnetic field of forces. Even if only *one* atom of copper combines with one nitrogen atom of the attached protein and converts this diamagnetic nitrogen into a paramagnetic one, thousands of nitrogen atoms of the crystal-like polypeptide chain structure may be affected and become also paramagnetic. These polypeptide chains are now able to transfer wandering electrons and use them where they are of greatest need.

SUMMARY

The mechanism of many chemical biochemical reactions is governed by the nature or type of bondings of the atoms or atom groupings attached to the central metal atom. In the resulting compound the electronic structure of the metal might become altered considerably, and the attached atomic grouping may as well change chemical and spatial structure after having donated or accepted electrons. It is known by experience that the number and arrangement of electrons in a metal determine its characteristic mode of bonding other atoms, molecules, or groups. The writer has found a simple chemical reaction (B reaction) in which copper is almost unique in behaving as a central atom. The knowledge of the mechanism of the reaction should throw light on the uniqueness of copper in certain enzyme reactions. If NO is linked to cuprous ions, a water-soluble radical [CuNO] is formed in which the nitrogen atom

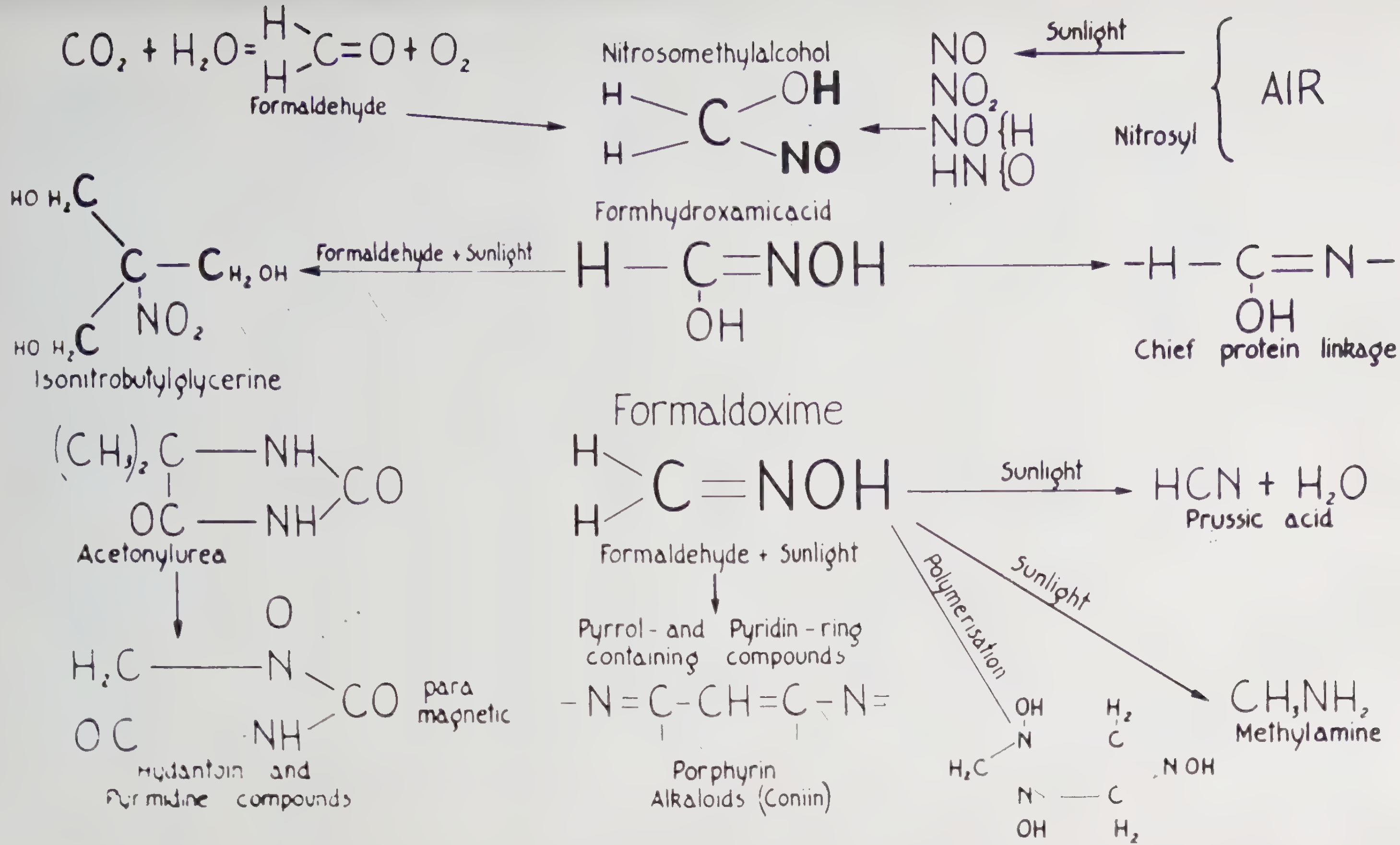


Figure 5.—Geochemistry of Carbon and Nitrogen—Formation of Organic Compounds from Inorganic by the Influence of Light.

I and W. Noddack	2	3	4	5	6	7	8	9	10	11	12
SPECIES	SEA SQUIRTS (ASCIDIAN)	SPONGES (SPONGIA)	JELLY FISHES (ACALEPH)	SEA ANEMONES (ACTINIA)	SEA CUCUMBERS (HALOTHURIAN)	SEA URCHINS (ECHINOID)	STAR FISHES (ASTEROID)	SMALL FISHES (LIPP FISH)	SHARKS	CONCENTRATION IN SEA WATER MICROGRAMS PER KILOGRAM	AVERAGE ENRICHMENT FACTOR IN THE ANIMALS COMPARED TO SEA WATER
INDIVIDUAL	CIONA INTESTINALIS	HALICHONDRIA	CYANEA CAPILLATA	METRIDIUM DIANTHUS	STICHOPUS TREMULUS	BRISSOPSIS LYRIFERA	ASTERIAS RUBENS	CTENOLABRUS RUPESTRIS	SQUALUS ACANTHIUS		
	WHOLE ANIMAL	WHOLE ANIMAL	WHOLE ANIMAL	WHOLE ANIMAL	WITHOUT INTESTINES	SHELL ONLY	WITHOUT INTESTINES	WHOLE ANIMAL	WITHOUT INTESTINES		
TITANIUM	1,700	8,400	6,000	7,300	4,300	4,800	5,000	7,000	700	< 0.5	> 10,000
VANADIUM	620,000	30,000	5,000	40,000	57,000	5,000	9,000	1,600	1,800	< 0.3	> 280,000
CHROMIUM	——	200	1,300	——	900	20	20	——	200	< 0.2	1,400
MOLYBDENUM	800	200	2,000	18,000	2,600	100	2,400	500	200	0.5	6,000
MANGANESE	120,000	58,000	60,000	55,000	37,000	530,000	190,000	43,000	3,500	3	41,000
IRON	250,000	2,500,000	150,000	620,000	410,000	570,000	900,000	330,000	460,000	6	86,000
COBALT	2,300	50	7,100	1,700	1,200	2,000	900	3,800	100	0.1	21,000
NICKEL	16,000	22,000	30,000	23,000	38,000	2,100	24,000	30,000	300	0.5	41,000
COPPER	13,000	34,000	68,000	32,000	17,000	18,000	18,000	53,000	18,000	4	7,500
SILVER	——	1,000	3,800	6,000	2,600	1,500	3,800	11,000	——	0.15	22,000
GOLD	——	10	7	7	24	7	30	10	——	0.008	1,400
ZINC	330,000	150,000	1,550,000	1,400,000	140,000	65,000	160,000	140,000	155,000	14	32,500
CADMIUM	600	1,100	11,000	400	2,600	30	1,700	3,000	——	< 0.5	> 4,500
GALLIUM	200	200	600	400	500	700	700	200	100	0.5	800
THALLIUM	——	——	30	30	3	1	3	——	——	< 0.01	700
GERMANIUM	400	300	2,200	700	300	70	300	2,200	400	< 0.1	> 7,600
TIN	3,500	1,700	32,000	15,000	6,200	1,600	7,200	4,700	2,000	3	2,700
LEAD	1,100	5,500	27,000	43,000	21,000	5,200	15,000	400	200	5	2,600
ARSENIC	3,000	5,000	50,000	9,000	2,000	8,000	4,000	12,000	6,000	3	3,300
ANTIMONY	100	80	160	230	240	180	100	200	200	< 0.5	> 300
BISMUTH	200	600	400	160	270	30	30	50	25	0.2	1,000
TOTAL	1,363,000	2,817,000	2,007,000	2,272,000	743,000	1,214,000	1,342,000	643,000	648,000	< 44.1	

Figure 6. Heavy Metals in Sea Animals—Concentrations in micrograms per kilogram of Dry Matter (one microgram equals one millionth of a gram or one gamma)

possesses a great reactivity and unites with aromatic hydrocarbons at room temperature. NO linked to cuprous ions also represents a new source for nitrosyl, NOH. The experiences obtained in studying the mechanism of the B reaction are discussed in connection with enzymatic reactions.

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THE PRESENT STATUS OF MINOR ELEMENT STUDIES IN FLORIDA

R. V. ALLISON*

There seems to be an inclination among those who are acquainted with the broad, potential scope of work with the "trace" or "minor" elements in Florida to feel that, as yet, we have scarcely "scratched the surface" in this extensive area of effort.

While this may be quite a realistic viewpoint towards the field as a whole, nevertheless a great deal has been accomplished since the earliest observations of the benefits of copper on citrus in the prevention and cure of dieback and the dramatic response of practically all crops to a number of these elements, notably copper, manganese and zinc on the raw, peat soils of the Everglades.

The same steady development has followed in animal nutrition as a result of the early relationship observed between the availability of adequate quantities of copper and of iron in the animal ration and the occurrence of the so-called "salt-sick" condition among cattle on the range, a malady that apparently has much in common with maladjustments in human metabolism known to occur in generally similar areas in Florida as reported by Drs. Abbott and Ahmann in Proc. Vol. II, Soil Science Society of Florida, pp. 109-115 (1940). As a matter of fact such maladjustments in animal and human nutrition may be regarded as having considerable in common with the dieback of citrus; certainly they go back to soil deficiencies in the essential elements involved in a very definite way. It is this relationship that I would like to discuss and emphasize rather more than any other in the brief time allotted to this purpose. I am sure that Dr. Abbott and Dr. Ahmann would join me in the hope that work in this field of human nutrition soon may be brought more into balance with that in animal nutrition since the latter is certainly well in advance of the former at the present time.

The first question that might well be raised is just what is meant by the "trace" or "minor" elements as we have come to recognize and use them in relation to all levels of nutrition and health, as well as growth, in plants, animals and humans and in the relation of the first to the second and the first two to the third as well as all three of them to the soil and its proper management and treatment as a medium for plant growth. Out of all this has been developed the logical sequence or series of readily integrated relationships which we have been discussing ever since they first became so obvious in the early work here in Florida a little less than two decades ago, namely the SOIL, the PLANT, the ANIMAL and MAN. In any event this approach would make it quite obvious that there is little in our agricultural research that is not meant, sooner or later, to improve the happiness and welfare of man with particular reference, of course, to his every day well being and health.

* Vice Director in Charge, Everglades Experiment Station, Belle Glade since July 1. Formerly Head, Soils Department, College of Agriculture, University of Florida, Gainesville.


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One of the simpler definitions for these elements that has been quite frequently used is "Those not ordinarily found in the fertilizer formula". This, of course, refers, in a negative way, to nitrogen, phosphoric acid and potash but is scarcely adequate in the case of a number of still other elements since calcium, magnesium and sulfur have been known as essential to all forms of plant growth for many years and are certainly required in greater quantities than "traces" though they are not given a place in the fertilizer formula, however much of one or all of them may be present in a particular mixture.

Figure 2.—Citrus leaves from trees in poor condition in Davie area where manganese response was first established and reported on as early as 1931, Proc. State Hort. Soc. Vol. 44, p. 21. This first result was with manganese and sulfur on areas where the peat was so shallow that underlying marl was brought into the immediate planting area of the trees in the top of the ridge by the ridging operation. This photo by J. R. Neller, 1934.

More recently we have come to recognize as essential elements at one level of nutrition or another—copper, manganese, zinc, boron and cobalt as well as iron, and refer to them as trace or minor elements because of the amazingly small amounts of them that seem to be required for satisfactory nutrition in the plant as well as in the animal. It is possible.

Figure 1.—Response of citrus, plum, peach and tung trees to light treatment of raw, Everglades peat with copper as copper sulfate, ½ lb. per tree as a supplement to general treatment with phosphate and potash. Photos taken March, 1931, one year after trees were set. All citrus varieties on sour orange stock; LEFT, untreated with copper; RIGHT, treated with copper. A. Duncan grapefruit, B. Pineapple orange, C. Dancy tangerine, D. Villa Franca lemon, E. Tahiti lime, F. Excelsior plum, G. Jewel peach, H. Tung.

Figure 3.—Response of sunflowers to treatment of normal (unburned), Everglades peat with copper as copper sulfate. Photographs taken July, 1929. A. Check (P and K only). B. Plus manganese (MnPK). C. Plus copper (CuPK). D. Plus Cu and Mn (CuMnPK).

of course, that, in time, as the novelty of such unusual findings wears off we shall come to drop such designations entirely and simply refer to the elements as essential or non-essential according to our knowledge of their activity and essentiality at a particular time.

Figure 4.—Response of Shallu ("Egyptian wheat") to treatment of normal (unburned) sawgrass soil with copper and manganese as sulfates. Pho ographs taken July, 1929. A. Check (P. & K only). B. Plus copper (CuPK). C. Plus copper and manganese (CuMnPK).

As a matter of fact there are presently those, as most of you know, who hold that all elements are essential to living things, and that our imperfect knowledge or complete ignorance of the essentiality of many of them is due, largely, to the complete inadequacy of our best analytical methods and experimental techniques to study them in a completely revealing manner. Indeed, as our understanding of the vital nature of the requirements of animals and humans, as well as plants, in terms of such elements grows and we come to better understand the exceedingly small amounts required it would seem to give substantial credence to this viewpoint. A very reasonable illustration of the above is currently to be found in the recent work with cobalt which is being reported on quite extensively in animal work and will be referred to below, briefly, in connection with some recent work with cotton.

Figure 5.—Response of sunflowers to treatment of burned, Everglades peat, pH 7.5 to 8.0, with manganese, sulfur and green manure. Photographs taken September, 1930. A. Check (P & K only). B. Plus manganese (MnPK). C. Plus copper and manganese—as sulfate (CuMnPK). D. Plus copper and manganese—as carbonate (CuMnPK). E. Check plus inoculated sulfur at 2500 lbs./A. F. Check plus green manure, 10 T./A.

While there are some who maintain that the natural composition of the soil or of the fertilizers that have been or are being added to it are largely unrelated to and without appreciable influence on plant composition, this view is definitely discredited by a great many soil and plant analyses. Thus, only last season, studies with Sea Island cotton (Variety Seabrook, Z-8 on Norfolk fine sand) showed increases of the element cobalt in the leaves and seed of the plant to the extent of 150 to 500 times that of those parts in plants growing on untreated areas. This was the result of a side-dressing with cobalt sulfate at the rate of 2½ pounds per acre! While studies to date have not shown a definite relationship of cobalt to plant growth per se, i.e., in terms of total growth, at least under such conditions of control as it has been possible to maintain in work of this nature in the past, such a composition response on the part of the plant to cobalt as is indicated above could certainly find a tremendous response in animals and humans consuming such materials as feeds or foods because of the very critical essentiality of this element in the metabolism of living creatures. Innumerable investigations are beginning to point to the need for studying our soil deficiencies in terms of such plant requirements as are necessary not alone for improved yields

Figure 6.—Response of sugar cane to treatment of normal sawgrass peat with copper and of burned sawgrass peat (pH 7.3 to 7.6) with manganese sulfate. Photographs taken October 1927 for A and July 1929 for B and C. A. Sugar cane variety U. S. 663 growing on raw, sawgrass peat with treatment of 30 pounds of copper sulfate per acre, only. Inset, same cane variety, soil condition and age without the copper treatment. B. Three cane varieties, left to right, P. O. J. 36, P. O. J. 36-M and S. C. 12/4 growing on burned sawgrass peat with CuPK treatment but without manganese. C. Same sugar cane varieties and same general soil condition and treatment as in "B" but with the inclusion of manganese sulfate.

Figure 7.—Response of Irish potato to treatment of burned sawgrass peat with manganese as a fertilizer and as a foliage spray. Photographs taken April 1931 for A thru D and November, 1931 for E and F. A. Check, no treatment. B. CuPK. C. CuMnPK, manganese in sulfate form. D. CuMnPK, manganese in carbonate form. E. CuPK only with spray of Bordeaux mixture. F. Same as "E" with inclusion of ½ percent manganese sulfate in the spray.

but for quality values as well from the nutritional standpoint for animals as well as humans when the plants are to be used as feeds or for food.

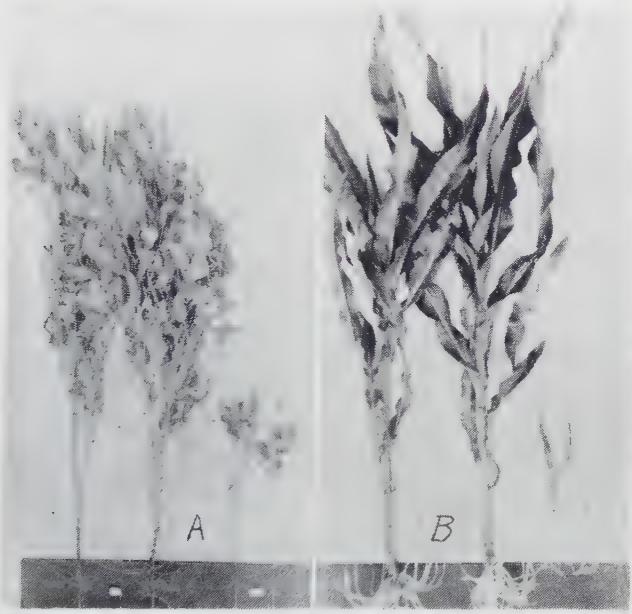

Figure 8.—Response of soybean and corn to treatment of raw, sawgrass peat with copper as copper sulfate. Photographs taken July, 1929. A. Biloxi soybeans, left, with copper at 30 lbs. per acre and, right, no treatment. B. Cuban flint corn, left, with copper at 30 lbs. per acre and, right, no treatment.

Many questions immediately arise, of course, when such critical values are sought. Detailed studies of considerable complexity certainly will be necessary to develop the requisite answers in the future. This is readily apparent when consideration is given to (1) the great number of soil types we must work with; (2) the equally great number of feed and food plants that are involved in our overall economy; (3) the ever increasing number of plant food elements that are coming into the picture; and, finally, (4) the possible interplay of these elements on each other insofar as certain crops in certain soils may be concerned. This, of course, will bring into view the problems of residues and the "toxicities" that may develop from them and the reactions that may develop among them An instance in point in this latter regard might be cited in the case of phosphorus which is being discussed before another symposium of this meeting as related to the actual availability of copper to citrus under certain conditions. Under other circumstances excesses of copper or other of the trace elements might develop particularly under conditions where the grower has come to appreciate the benefit of one or more of these special elements and simply continued the application, regularly, perhaps in ever-increasing quantities, without troubling to check on the accumulation that may be developing in his soil.

Inasmuch as some of you may not have seen any of the trace element responses in the field to which reference has been made I should like to show you a number of them as slides. These are entirely concerned with the early responses that developed on the Everglades peat of South Florida which have been of such indispensible importance in the agricultural development of that great area and particularly emphasize copper, manganese and zinc. Of those that are shown on the slides that follow only some of the more typical will be included in the published record.

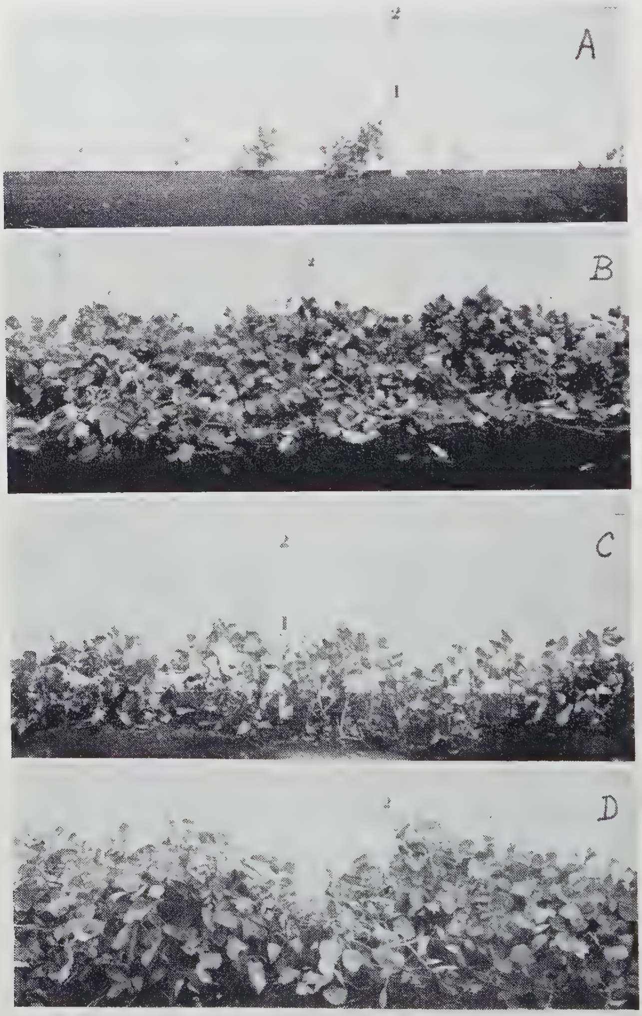

Figure 9.—Response of cowpeas, variety Brabham, to treatment of burned sawgrass peat (A and B) with manganese sulfate and of normal (unburned) peat soil (C and D) with copper as copper sulfate. Photographs taken July, 1929. Burned peat: A. Check (CuPK). B Plus manganese (CuMnPK). Normal peat: C. Check (MnPK). D. Plus copper (CuMnPK).

Figure 10.—Response of Little Spanish peanuts to treatment of normal Everglades peat with copper and zinc in the form of their sulfates. Photographs taken in October, 1927 for "A" and in June, 1928 for B, C and D. A. Left, no treatment. Right, copper sulfate only, at 30 lbs./A. Middle, copper and zinc sulfate combination, defoliation being due to earlier response to combination treatment and, consequently, to earlier maturity than in the copper treatment alone. Zinc was used at about 10 pounds per acre. B. Rosetted and stunted condition of peanut plants in the absence of copper treatment. C. Close-up of single plant similar to those shown in "B". D. Center, background, no treatment. Center, foreground, manganese and zinc. Left, foreground, copper and zinc. Right, foreground, copper, manganese and zinc.

Figure 11.—Response of kohlrabi and endive to treatment of raw, sawgrass peat exclusively with copper and manganese sulfates at the rate of 30 pounds per acre and with stable manure in the absence of any other fertilizer treatment in each instance. Photographs taken May, 1927. Above—Kohlrabi: 1. Copper only. 2. Manganese only. 3. Stable manure only. 4. Check, no treatment. Below—Endive: 1. Copper only. 2. Manganese only. 3. Stable manure only. 4. Check, no treatment.

The complexity which the work with trace elements has brought into our research program, as well as the good they have done, is well indicated by the fact that they have not only made possible the agricultural development of the Everglades area—truck crops, pasture, sugar cane and many others, but an elaborate program of their use (copper, manganese and zinc) on a wide scale is being developed for citrus and other tree crops such as pecan, tung and peach on many of the more important mineral soils of the State; also for truck crops, pasture and many other farm crops on these soils and on the marls, as well, where boron also is frequently found to play an important part. Indeed it is rapidly becoming apparent that Florida soils are not alone in these deficiencies for they are beginning to crop up in many different parts of the country and of

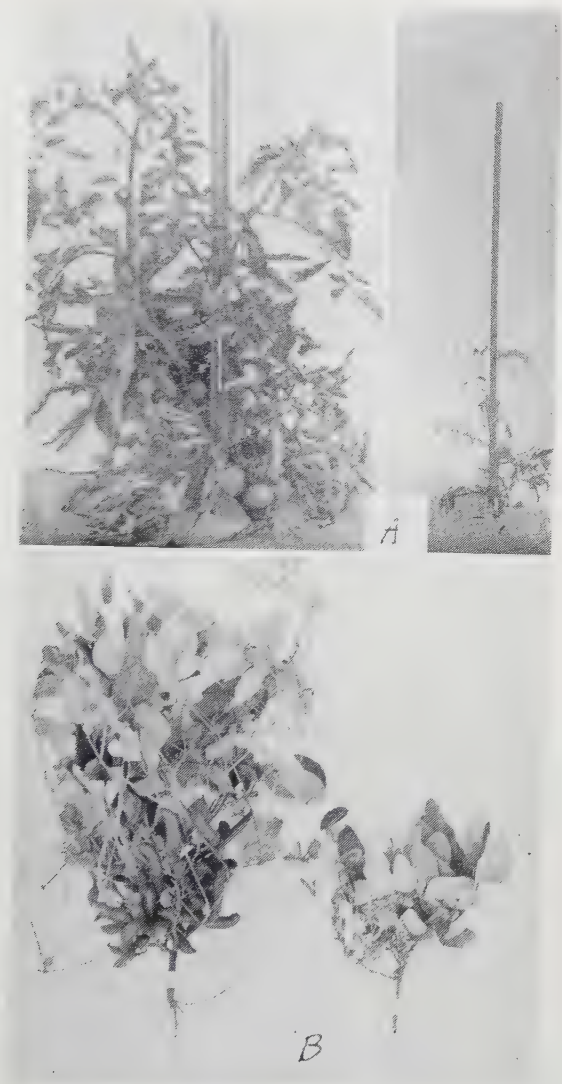

Figure 12.—Response of tomato and of early Tracy velvet bean to treatment of raw, sawgrass peat exclusively with copper sulfate at the rate of 30 pounds per acre. Photographs taken May, 1927 for "A" and July, 1927 for "B". A. Tomato plants—left, treated with copper; right, untreated. B. Early Tracy velvet bean -left, treated with copper; right, untreated.

the world as the result of a more critical examination of local needs both as to plant and animal nutrition.

In closing, it is believed that an angle of study which should be more emphasized in the future than it has been in the past is that of "insoluble" sources of at least some of these trace elements. This is for two particular reasons (1) lower cost and (2) less leaching due to slower solubility. This would find perfect corollary in our present studies with insoluble sources of phosphorus whether as finely ground rock or waste pond materials from phosphate operations more commonly known as "colloidal".

Natural ores containing the various trace elements are to be had in which the degree of insolubility is about the same as the natural phosphates. The main question that is posed is whether the cost of reducing these elements to soluble and more refined form for use as soil amendments is justified in the face of the solubility and leaching factors referred to above. After all, plants growing in soils that are naturally fertile and adequate for growth find these elements in their natural mineral state for the most part and are not given the advantage of a predigestive treatment. It is believed that herein lies a problem that could well be given very careful study. Nor is it believed that in advance of such careful studies these natural minerals should be given such special treatments as fritting and other preparations than grinding to requisite fineness since this could readily add costs to the materials which may be neither necessary nor economically justified.

METHODS OF ANALYSIS FOR MINOR ELEMENTS IN SOIL AND PLANT MATERIALS

T. C. Erwin, R. A. Carrigan, L. H. Rogers and J. N. Howard

As interest grew in minor element studies, it was found that much of the necessary research was handicapped by a lack of suitable analytical methods. The concentration of some of these elements is so low that reagents which had been considered pure were found to be unsatisfactory and much purification work had to be done. In many cases ordinary glassware could not be used as it would introduce contamination. Special care in the collection and handling of samples had to be developed. A constant guard had to be set up against contamination by or loss of the element. It was found that in some methods the loss due to adsorption and occlusion in filtering processes was much too large to be neglected. However, in recent years much progress has been made and is continuing to be made.

In Florida considerable attention has been given to the following elements: Cu, Zn, Co, B, Fe, Mn and Mo. In considering the methods now being used to determine the quantities of these elements found in our soils and plant materials, the amounts will be given in p.p.m. on the oven dry basis.

First, there is the spectrographic rough estimate method, which includes all of these elements and 30 others. The range of this method is from 10 to 1,000 p.p.m. in soils and from 1 to 100 p.p.m. in plant material. However, this method will indicate differences only when they are twofold or larger. Therefore, its use is limited to general survey work and preliminary determination of concentration ranges for which quantitative methods should be developed.

Copper analyses of plant material are now being run by diethyldithiocarbamate colorimetric methods and by spectrographic methods. The colorimetric and spectrographic methods of several workers have been compared and were found to agree very well. The range covered was from 10 to 80 p.p.m. of copper in dry plant material. Quantitative spectrographic determinations have shown copper from 2 to 80 p.p.m. in plant material and from 1 to 1,000 p.p.m. in soils.

Zinc is now being run by dithizone colorimetric methods and a range of from 5 to 400 p.p.m. of zinc has been found in plant material. The total zinc found in untreated soils runs from 10 to 200 p.p.m.

Cobalt is being run on plant material by a Nitroso-R-salt colorimetric method and by a spectrographic method. The range covered is from .01 to 30 p.p.m. It was found that the cobalt in many of our light sandy soils was below this range. Therefore, a spectrographic method has been developed in which the cobalt is extracted from the soil with dilute hydrochloric acid and then concentrated with the aid of dithizone prior to the actual spectrographic test. With this method soil analyses have been made in which cobalt varied from .002 to 20 p.p.m. According to work done in cooperation with the Animal Industry Department, there

is an apparent critical level for cobalt in soils of about .02 p.p.m., based on extraction with N/10 hydrochloric acid. It must be kept in mind that this is probably not total or available cobalt and can be used only for comparisons.

A turmeric colorimetric method is being used for determining boron in plant material and boiling-water-soluble boron in soils. This method shows that the boiling-water-soluble boron in soils will vary from .1 to 1 p.p.m. where no boron has been added. The spectrographic rough estimate method indicates that the total boron varies from 10 to 200 p.p.m. Plant material is found to contain from 10 to 20 p.p.m. of boron. This level is sometimes increased by several hundred per cent where heavy boron treatment is used.

Iron is being run by a thiocyanate colorimetric method. The range covered in plant material is from 25 to 250 p.p.m. Almost all soils have more than 1000 p.p.m. of iron: however, the readily soluble iron is quite small for some of these soils.

Manganese is being run by an ammonium persulphate colorimetric method. The manganese in some plants varies greatly, ranging from 15 to 5000 p.p.m. The manganese in soils ranges from 10 to 5000 p.p.m.

Comparisons have been made of spectrographic, colorimetric and polarographic methods for molybdenum. While making these comparisons it was found that the molybdenum content of various grasses ranged from 2 to 40 p.p.m. and that molybdenum in peat and muck soils ranges from 1 to 10 p.p.m.

One of the newest developments in this state is the introduction of tracer elements into the study of minor elements. The use of these radioactive elements makes it possible to study the movement of an element in a living plant or animal, and makes possible a quantitative analysis of very minute quantities of the element.

As work continues much of value may be derived from a more complete compilation of information obtained in Florida concerning methods used, analyses for and responses to minor elements. The elements which are now being studied include most of those to which we might expect biological response, according to Steinberg.[1] There are indications that efforts should be made to obtain a better understanding of the possible roles of certain other elements in plant growth such as aluminum, sulfur, iodine, sodium, chlorine, scandium, gallium, strontium and barium.

Chairman Allison:*

Dr. B. R. Fudge will now discuss Mr. Erwin's paper.

Dr. Fudge:

It has been my pleasure to work with the Soils Department for the past few years and I take this opportunity to express my thanks and appreciation for the cooperation we have been receiving. I am interested, of course, entirely in colormetric methods for such elements as copper and zinc.

In opening this discussion, I think continued emphasis should be given to the six minor or secondary elements that are now quite extensively under study. It is readily apparent that the use of these so-called trace elements or minor elements during the past 10 or 15 years in Agricultural Experiment Stations has become greatly extended.

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[1] Influence of carbon dioxide on response of aspergillus niger to trace elements. Steinberg, R. A. Plant Physiol. **17**, 129-32 (1942).

* Acting in the absence of Chairman Volk who was absent during the afternoon and evening meetings on account of illness.

Certainly the improved use of colormetric methods has taken some of the error out of visual comparison, and I think they are now quite acceptable and the results quite comparable, with perhaps a few allowances, for such elements as copper and zinc.

In connection with the very interesting talk by Dr. Baudisch this morning, I was particularly interested in asking, and I should now like to ask, whether or not the continued use of copper under field conditions might produce a level of concentration that would cause damage to citrus. Please understand that sometimes the grower is placing as much as a pound of copper sulphate around the tree at rather frequent intervals. This quantity, if entirely soluble, and if it were in a nutrient solution would indeed be toxic to the tree. The soil is interposed, of course, and absorbs a substantial amount. I am wondering, however, if we should not be more careful in using these elements too freely, at least until such time as we have adequate methods to check them with a reasonable degree of accuracy.

Another point I am especially interested in is the fact that 1,000 parts per million of copper in some soils, as revealed by the survey work in progress, should give some indication of what elements interfere with each other.

Dr. Baudisch:

I think I had better discuss the matter with you later.

DEFICIENCY STUDIES AMONG THE CATTLE OF OSCEOLA COUNTY

June Gunn*

Dr. Davis will discuss the Chemical and Biological methods involved in the study of mineral deficiencies among the cattle of Osceola County, as he has been in charge of this work.

It has been my privilege, as the County Agricultural Agent and interested in a small herd of cattle, to be a part of the cattle industry of Osceola County for the past twenty-one years.

In my close association with cattlemen, cattle and pastures during this period, a lot of observations have been made. Cattlemen, who are always close observers, knew that cattle could not be kept on one pasture for too long a period long before my time in the county.

In the days of open range, cattlemen made it a practice to move cattle frequently. The cattle were moved to the hills in the Fall and brought back to the prairies in the Spring. Woods were burned in the Fall and the ashes were thought to cure the "marsh sick" cattle.

Certain pastures are known as steer pastures, or fattening pastures but are not any good for "raising pastures". Mature cattle put in these pastures do well and fatten quickly but young stock or cows carrying calves "go to pieces", "get sick", or "take rheumatism".

Such names as "salt sick", "marsh sick", "hollow belly", "stiffs" and rheumatism have long been common where cattle would get out of condition because of deficiencies.

It has long been a common observation to see cattle chewing on old bones and when moving herds, they will pick up pieces of lime rock when crossing railroads or highways. Quite frequently cattle are found with tin cans or other pieces of metal in their mouths and, in a few instances in driving herds, cattle have even been seen picking up live snakes and trying to eat them.

With the development of the county and of the cattle improvement program, open range has become a thing of the past. Cattle are now confined to given areas. For this reason they cannot be moved to different types of soils as freely as they were in the past. Also, as the size of the cattle have increased these deficiency problems have become more acute.

Before our Experiment Station gave us the mineral mixtures, cattlemen generally were complaining that the improved breeding program was not a success because the better bred cattle would not "stand up" on their ranges.

When mineral boxes were put in the pastures this condition gradually began to correct itself to a very definite degree. However, this has not completely solved our problem as some individuals will not take minerals from the boxes and it is also quite a problem to keep all boxes filled in large pastures, which are quite often long distances from headquarters.

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* County Agricultural Agent, Osceola County, Kissimmee.

Since the soil conservation program has been in operation quite a number of cattlemen has been putting applications of either rock or superphosphate on areas in their pastures. In every instance the average cattleman can see a very marked improvement in the stock which graze on these phosphated areas.

Osceola County, like many other counties in this state and other states cannot produce or maintain high quality cattle without mineral supplements. Some of our cattlemen have experienced outstanding results in pastures of the county by putting boxes at convenient places over the pastures and with three compartments. In one section they put bone meal, salt in another and in the third compartment the Experiment Station's mixture of salt, red oxide of iron, copper and cobalt.

In other pastures these materials in the boxes are not giving us the proper results. Whether there are other deficiencies or whether we do not have the right proportions for all types of pastures, we still do not know. Mineral deficiencies constitute a very definite economic problem in Osceola County and in the entire Kissimmee Valley as a whole. If definite figures could be obtained on the loss sustained by cattle producers, it would run into an enormous sum. This figure would include loss in pounds of meat caused by cattle not making proper gains and in the actual loss of cattle by deaths where these deficiencies are not corrected. It would also include cattle which have to be destroyed when bones are broken in handling where the phosphorus deficiency is so serious and the bone structure is so depleted that there is not a sufficient amount of this element to properly maintain the framework of the animal against ordinary handling.

CHEMICAL AND BIOLOGICAL METHODS INVOLVED IN THE STUDY OF MINERAL DEFICIENCIES AMONG THE CATTLE OF OSCEOLA COUNTY

George K. Davis*

In limiting this topic to Osceola County there is no intention of singling out this county as possessing unusual and different conditions than exist in other counties in the State of Florida or United States. Rather, an effort was made to bring the problem closer home and to call attention to some of the difficulties which face us in trying to work out the problems in animal nutrition under practical animal husbandry conditions.

Probably the best approach to this topic is to indicate some of the conditions which we have found existing in Osceola County. Of primary importance is the condition due to a deficiency of phosphorus. In the more or less classical description of phosphorus deficiency in cattle, the animals lose appetite, grow rough hair coat, the bones become easily fractured, there is a perversion of appetite with the animals craving any type of unusual material as feed ranging all the way from glass bottles to old hats, but having a particular preference for pine knots, wood fences and bones. The animals lose weight, make poor use of what feed they do consume, and the blood inorganic phosphorus value usually drops to somewhere in the neighborhood of 2 to 3 mg. per 100 cc. of blood plasma.

In Osceola County, this type of phosphorus deficiency has not developed to any appreciable extent. There have been several diversifications which are nonetheless related to phosphorus deficiency. Along some parts of the marshes of the St. Johns River, cattle have been found with inorganic phosphorus values below 1 mg. per 100 ml. of plasma. These cattle are able to move around, and are apparently without depraved appetite. A very definite rarefication of the bones occurs with the development in some animals of what is known as rheumatism or "stiffs". Another condition which apparently develops in this county in some areas is the appearance of rickets-like syndromes in calves which are receiving adequate calcium and phosphorus, so far as our present standards go. In some way this phosphorus has been rendered unavailable to these calves. In another section of the county there develops a phosphorus deficiency which shows up principally as a loss of condition and is very definitely related to the utilization of available feed. All of these conditions are related to phosphorus deficiency in one way or another, although none completely fits the usual picture of phosphorus deficiency.

In studying manifestations of phosphorus deficiency we have relied first upon the use of our blood analysis techniques for the determination of inorganic phosphorus. This has given us some results which are difficult to interpret. For instance, some fairly poor cattle, but far from the worst we have seen, have had blood inorganic phosphorus values as low

* Animal Nutritionist and Biochemist, Florida Agricultural Experiment Station, Gainesville.

as .7 mg. per 100 ml. of blood plasma. Values of from 4 to 6 mg. per 100 ml. in cattle have been found which are in much worse condition than those previously mentioned but showing phosphorus deficiency symptoms. These values alone do not show a true picture and we are immediately faced with the limitation of our usual blood chemistry methods. We have reason to believe that they are demonstrating values for phosphorus that are actually present in the blood. However, to interpret these values in terms of remedial measures is impossible, without further information. This necessitates the use of other methods, biological methods, in which rats and rabbits, as well as cattle themselves, are used as the experimental animals.

One thing that has shown up in some of our preliminary work with small animals is that with our experimental rations the small animals have not portrayed the same difficulties as are experienced with cattle. We are able to develop a phosphorus deficiency but not with the variations seen in cattle. There may be several reasons for this. One is that the forage which we must feed is difficult to obtain in a state approximating that seen in these areas. What happens to the nutritive quality of forage upon storage is still a difficult question to answer. Our chemical analyses of the forage itself indicates an extremely low phosphorus content, however, there have been enough variations to indicate that this alone is not an index of the value or lack of value of this forage as a source of phosphorus for animal nutrition. At least in the small animal the phosphorus is not equally available to the animals from all forages.

This brings us back to the large animal studies, from which we can only say that what evidence we have indicates unequal availability of phosphorus from different plant sources, why we cannot say as yet.

In the study of phosphorus in the nutrition of cattle in Osceola County, it has become necessary to consider developing new criteria of phosphorus nutrition in the cattle, and second, we have to depend to a considerable extent upon the cattle themselves to give us an index of the phosphorus that is available to the animals in the different sections. One other method which we hope to expand in the future is the use of tracer elements, having in mind the tracing of the movement of labeled elements through the metabolism of the animal. As you all will realize, the study of phosphorus in nutrition cannot be separated from the study of calcium since both of these elements are closely allied in the metabolism of the animal. Fortunately and unfortunately in Osceola County phosphorus has always been the limiting factor. Actually phosphorus is the limiting element in many areas, overshadowing the symtoms of other deficiencies which may become apparent when the phosphorus deficiency is remedied.

Most of you have heard of "salt sick" in cattle. It is a condition that is difficult to describe accurately. It appears to be the result of a deficiency singly or together of cobalt, copper and possibly iron. It has occurred in Osceola County and many of the other counties of Florida. It appears as a loss of appetite, extremely emaciated condition of the animals, a more or less marked anemia, a roughened hair coat, and failure of the animal to shed in the spring. In studying this problem, we have chosen at present to concentrate our efforts on cobalt. Principally because of the minute concentration in which cobalt occurs it has been elusive so far as our methods of analysis are concerned. Most

of the methods for cobalt have been valueless when it comes to the analysis of biological plant and animal material containing physiological amounts of cobalt. The production of a cobalt deficiency with certainty, artificially, is extremely difficult and perhaps impossible in any but ruminants.

At the present time we are using two methods in our work in the study of cobalt deficiency in cattle. The first is a microchemical method in which the cobalt is concentrated and then determined by use of a nitroso-R-Salt in the photolometer. This has enabled us to distinguish between so-called "healthy" and "salt sick" ranches, but still leaves room for improvement, particularly in the analysis of animal tissues. We have also turned to the use of radioactive cobalt as a tracer element and, with this, hope to follow the progress of cobalt through the animal identifying if possible the locality of its function and what this function is.

Copper, another of the deficient elements, presents a slightly different problem in that a deficiency can be readily demonstrated in small animals and studied from this angle. It is also here more easily determined by microchemical methods, and we have used both methods in studies of mineral deficiencies. Because iron and copper are linked together in their action, we have also been studying iron and its function in small animals as related to the needs of the large animals. Because the problem has always been complicated by other deficiencies, we are still not in a position to say that iron is or is not a deficiency occurring in the cattle of Osceola County.

Histological studies of the blood cells also give promise of identifying deficiencies so far as iron, copper and cobalt are concerned, by variations in the morphology of the cells and the concentration of hemoglobin within them.

In conclusion: We are applying all of the methods and techniques which we believe are applicable to the study of mineral deficiencies of the cattle of Osceola County. The difference between the methods used here and in other parts of the country hinges upon the fact that in Osceola County and other counties of Florida too, there are present mineral-deficiency conditions which have required us to develop new applications, and I suspect before we are through, entirely new techniques for the study of these multiple deficiencies.

CHAIRMAN:

Mr. J. R. Henderson will now discuss the papers by Messrs. Gunn and Davis.

J. R. HENDERSON:

I was particularly interested in the papers by Mr. Gunn and Dr. Davis in that both made reference to the fact that managers of pastures of various kinds needed to seek specific information.

I might point out some of the soils that have been included in the studies of "saltsick" up to the present time, starting 10 or 12 years ago, since I am quite familiar, from first-hand observation, with some of the areas examined and have had the privilege of observing some of the work that members of the Animal Husbandry Department have done during this period.

Apparently it is possible to tie some of these animal deficiencies back to certain soils and in that way we hope we can get a better picture of the area as related to the different types of deficiencies.

In 22 areas where "saltsick" was evidenced in cattle grazing on the land, seven of the soils involved were Leon fine sand, three of them Portsmouth fine sand, ten Norfolk fine sand and two were peat. Unfortunately, I didn't make a list of those where the cattle didn't show "saltsick". I will only point out that certain of the

better types of soil apparently contained sufficient amounts of these minerals to prevent "saltsick" from showing up in cattle.

After the study of cobalt was started it was found that apparently a number of ranchers over the state who had been using the recommended "saltsick" measures of the past still found their cattle showing symptoms of the disease. In most of these areas when only a little cobalt was included with the regular mixture the cattle recovered.

The 24 soils involved in these areas were about as follows: Norfolk 4; Blanton 6; Leon, etc., 6; Plummer 4; Lakewood 3; and Portsmouth 1. This would seem to indicate that, as far as the state as a whole is concerned, we can pretty well tie these deficiencies back to the soils on which they develop. In that way we can extend our knowledge over a larger area than we might otherwise be able to do.

EVIDENCE OF PHOSPHORUS INTERFERENCE IN THE ASSIMILATION OF COPPER BY CITRUS ON THE ORGANIC SOILS OF THE LOWER EAST COAST OF FLORIDA

W. T. Forsee, Jr. and R. V. Allison*

The use of copper as a soil amendment has become very general on the organic soils of South Florida. It has been found absolutely necessary for practically all crops, including tree crops, when grown on Everglades peat derived from sawgrass as well as many of the mineral soils marginal to the Everglades which have been influenced by sawgrass growth in the past.

The widespread use of copper in this way was initiated by early studies at the Everglades Experiment Station which demonstrated the tremendous growth response of crops following its application in practically any form to these soils. The first published report of these plant responses to such treatments was made in 1927 by Allison and others(2). Later experiments along this line with copper and other minor elements are reported in the annual reports of the Experiment Station from year to year as well as in numerous outside journals(1). More recently certain studies, conducted under greenhouse conditions, were reported by Forsee(6) in which the copper deficiency symptoms are described for a number of important vegetable crops growing in treated and untreated sawgrass soil.

An abnormal condition of citrus, commonly known as "exanthema" or "dieback", was first pointed out by Floyd(5) and subsequently described in greater detail by Camp and Fudge(4) and by Bryan(3). That this abnormal condition of growth in citrus may be fully overcome by applications of copper to the soil was definitely demonstrated by Allison(1) in 1931 for organic soils and by Fudge(8) in 1936 for mineral soils. Such a condition in citrus is now widely recognized as a copper deficiency symptom.

One of the initial indications of copper deficiency in citrus is the rather characteristic markings that appear on the fruit which are commonly referred to as "ammoniation". Since the conditions of "ammoniation" and "dieback" are now recognized as copper deficiency symptoms, it would seem reasonable to expect that samples of plant material from affected trees would be lower in copper content than corresponding samples from healthy trees. This assumption has been confirmed by Haas and Quayle(9) who found that leaves of "exanthema" affected citrus trees were lower in copper content than those from healthy trees. Furthermore, in experiments on Bartlett pear trees in central California, Oserkowsky and Thomas(12) found that the copper content of leaves and shoots from trees within an affected area was invariably lower than that from samples taken in localities entirely free from the abnormal condition. These authors further state, however, that there was no consistent

* Associate Chemist and Vice-Director-in-Charge, respectively, Everglades Experiment Station, Belle Glade, Florida.

difference in the copper content of samples from healthy and affected trees within an individual orchard exhibiting the copper deficiency symptoms.

By 1941 ammoniation symptoms had become quite evident on certain plots in a fertilizer experiment that was being conducted in a citrus grove in the Davie area along the eastern edge of the Everglades, Neller and Forsee(11). This condition of ammoniation was found to be restricted almost entirely to plots receiving the heavier of two rates of superphosphate application as outlined in Table 1. The extent and relation of this copper deficiency symptom to fertilizer treatment in this set of plots has been discussed in some detail by Forsee and Neller(7).

TABLE 1.—COPPER ANALYSIS OF CITRUS LEAVES AND FRUIT IN RELATION TO SOURCE AND RATE OF PHOSPHATE TREATMENT AND ACCOMPANYING AMMONIATION OBSERVED ON FRUIT.*

Phosphate Treatment**	Total Copper (p.p.m.)				Percent Ammoniation in Fruit Harvested	
	Soil†	Leaves†	Seed†	Juice	1943	1944
No Phosphorus	185	14.3	10.5	0.57	0.8	0.4
6% P_2O_5 (Super)	260	3 9	11.5	0 26	0 4	0.3
12% P_2O_5 (Super)	263	2.2	3.4	0.15	16.1	24.0
18% P_2O_5 (Rock)	......	3.6	......	......	0.2	0.1
6% P_2O_5 (Colloidal)	......	7.7	......	......	0.5	0.1
6% P_2O_5 (Slag)	......	7.1	......	......	0.6	0.1

* Soil and plant materials analyzed spectrographically by T. C. Erwin, Soils Department, Gainesville.

** Basic trea'ment: 3-6-12. The total P_2O_5 content of the phosphate materials was used in making up the various treatments.

† Oven dry basis.

A comparison of the percent of ammoniated fruit in the 1944 harvests from plots receiving various phosphate treatments, as outlined in Table 1, shows twenty-four percent for the higher twelve percent superphosphate treatment as against less than one percent for either the lower six percent superphosphate treatment or the less soluble sources of phosphate that were applied as colloidal phosphate, finely ground rock phosphate or basic slag. The data for the 1943 harvest is seen to follow the same general trend. These ammoniation data are based on counts made on the entire lots of fruit from the plots of these various treatments by Dr. T. W. Young of the Citrus Experiment Station as they passed over the grading belt at the packing house.

The soil analyses for copper show that the trees on the plots receiving superphosphate had access to as much or even more of this element than those on the plots receiving no phosphorus in the fertilizer. However, as the treatment was increased from no phosphate to a twelve percent phosphate fertilizer, with superphosphate as the source, the assimilation of copper decreased as is evidenced by the copper content of the leaves and juice. The much greater assimilation of copper by the plants on the no-phosphate treatment suggests a larger removal of copper by this

treatment and could possibly account for the lower average of total copper in the soil from this treatment. Leaf samples from the colloidal and basic slag treatments show copper values intermediate between the no-phosphate treatment and the six percent superphosphate treatment. In view of the fact that the phosphorus in those materials is much less soluble than that in superphosphate, this correlates fully with the indication that copper assimilation is inversely proportional to the amount of active phosphorus in the soil. Rock phosphate, having been applied at three times the rate of the other phosphate sources, shows a copper content in the leaves that is approximately the same as that of the foliage from the six percent phosphate plot where it was applied as superphosphate. The seed did not show a drop in copper content until the copper uptake was so low as to cause deficiency symptoms to become evident in the tree in the form of ammoniation.

The phosphorus content of the soil from some of the plots of this same experiment, as well as that of the leaves and juice of the fruit, is recorded in Table 2. Here it is seen that the phosphorus in the leaves and juice increased as the superphosphate treatments increased. The leaf analyses of the samples from the less soluble phosphate sources indicate that the amount of available phosphorus from these treatments is less than that from the six percent superphosphate treatment. The high amount of available phosphorus in the treatment involving 12 percent P_2O_5 from superphosphate is indicated by the soil test and reflected in the analyses of the leaf and juice samples. By referring back to Table 1, it is noted that the high percentage of ammoniation corresponds to this same treatment involving the high amount of active phosphate.

TABLE 2.—Phosphorus Analyses of Citrus Leaves and Fruit in Relation to Source and Rate of Phosphate Treatments and the Amount of Readily Soluble Phosphorus in the Soil.

Phosphate Treatment	Phosphorus (P) Content		Juice (p.p.m.)
	Soil* (Lbs. per A.)**	Leaves (Percent)**	
No Phosphorus	2.3	0.145	2.24
6% P_2O_5 (Super)	8.6	0.182	6.66
12% P_2O_5 (Super)	18.2	0.190	7.44
18% P_2O_5 (Rock)	24 5	0.172	......
6% P_2O_5 (Colloidal)	6 6	0 166	......
6% P_2O_5 (Slag)	9.7	0 174	......

* 0.5 *N* Acetic acid soluble.
** Oven dry basis.

In studying soils from rather widely different parts of Florida, Jamison(10) found little difference, by laboratory methods, in the fixation of copper in the presence and absence of superphosphate. While the data presented in this brief paper definitely indicate that soil applications of phosphorus influences copper assimilation by citrus trees growing on the soil type represented by the eastern margin of the Everglades, this influence may be indirect and not in the nature of straight fixation. Al-

though the relationship certainly does exist the question of the physical and chemical interactions between copper and phosphorus in the soil under the conditions of this study must be determined by further research on the subject.

CHAIRMAN:

Inasmuch as the discussion of this paper has been so extemporaneous and of such a rapid-fire nature as to prevent an accurate and adequate record I would like to add only the remarks that this apparent relationship between the assimilation of copper by citrus and phosphatic supplements in the fertilizer has been observed on several other crops for a number of years in our Everglades studies. In fact such observations go right back to the early responses in 1928. Particular reference might be made to such diverse crops as cabbage, peanuts, sugarcane and corn. Certainly there is an important problem to be followed up in all of this that is not only extremely interesting but highly important, as well, from a practical standpoint.

DR. HARRIS:

I think you might be interested in the fact that Willis, about 1930-32, published a paper about some of his results on the black, organic soils of North Carolina which are peaty types of land. As I recall it he got the same kind of result you were talking about, and while the details are not clear in my mind I think there was a distinct relationship.

CHAIRMAN:

I am sure your recollections in the matter are substantially correct. Our early studies with the trace elements on Everglades peat were relayed most enthusiastically to Dr. Willis by Dr. A. P. Dachnowski-Stokes, Peat Specialist of USDA, who was making systematic studies of our organic soils in the Everglades in 1928 and 29 while we were in the midst of our early studies with them and he subsequently spent considerable time in North Carolina on the same type of field investigations.

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BASE EXCHANGE CAPACITY OF SOME FLORIDA SOILS

L. E. Ensminger*

The phenomenon of ionic exchange in soils includes cation exchange as well as anion exchange. Cation exchange involves both hydrogen and bases and is commonly referred to as base exchange. The magnitude of the reaction is known as the base exchange capacity and is expressed as milliequivalents per 100 gm. soil.

In most soils two types of constituents contribute to the base exchange capacity, namely, inorganic and organic colloids. Weight for weight, the organic matter possesses an exchange capacity several times that of the inorganic fraction. The light sandy soils contain only small quantities of the inorganic colloids while the organic matter varies depending on the soil type and can be controlled somewhat by management practices.

Most soils contain a reserve supply of calcium, potassium, magnesium, etc., in the form of primary and secondary minerals which become available as these cations in the exchangeable form are removed by leaching or plant uptake. Since Florida soils contain little or no reserve supply of such nutrients, fertilizer and lime must be added to supply these nutrients. A soil with a high base exchange capacity will retain more of the cationic nutrients against leaching than one with a low capacity. Base exchange capacity is therefore very important from the standpoint of retention of nutrients added to the soil.

Base exchange capacity is usually measured by saturating a soil sample with the cation of a particular salt solution. After washing out the excess saturating solution with methyl or ethyl alcohol the adsorbed cation is replaced and determined. Various saturating salts have been used in the past but neutral ammonium acetate probably has been used more than any other salt for this purpose. The base exchange capacity of several soils was determined by saturating with the following acetate salts: ammonium, calcium, and barium. According to the data reported in Table 1 barium and calcium are adsorbed to the same extent in most cases while ammonium values on the average are only about 65 percent as high as the calcium and barium values. Calcium is the dominant base in most soils and therefore should come nearest to being a true measure of exchange capacity. Since barium gives the same capacity as calcium it seems to be a satisfactory cation to use for measuring exchange capacity.

It is generally recognized that the retention of bases in a given soil is greater in the slightly acid range than in the strongly acid range. Why this is true is not known for sure, but it may be due to the effect of pH on base exchange capacity. Data presented in Table 1 show that the pH of the saturating solution influences to a considerable extent the magnitude of the base exchange capacity of a particular soil. If the same relationship holds in the field, then one way to keep the base exchange capacity as high as possible is to keep the pH as high as consistent with the crops that are to be grown.

* Assistant Chemist, Soils Dept., Fla. Agr. Expt. Station, Gainesville.

TABLE 1.—BASE EXCHANGE CAPACITY AS INFLUENCED BY THE SATURATING CATION AND THE pH OF THE SATURATING SOLUTION.

Soil Type	Base Exchange Capacity in m.e. as Measured by Various Acetate Solutions					
	Ammonium Acetate		Calcium Acetate		Barium Acetate	
	pH 7.0	pH 5.0	pH 7.0	pH 5.0	pH 7.0	pH 5.0
Leon sand	5.5	3.7	8.4	6.3	7.9	5.5
Fellowship fine sandy loam	8 4	5.5	12.6	8.0	11 8	7.6
Portsmouth sand	14.5	7.0	21 5	13.9	22 8	16.8
Bayboro clay loam	32.0	17.3	44 4	28.5	45.3	29.4
Orangeburg fine sandy loam	5.3	3.3	8.4	5.1	7.7	5.4
Norfolk sand	2.9	2.0	5.5	2.6	4 5	2.9
Brighton peat	95 3	54.0	136.0	89.1	135.7	96.7
Everglades peat	144 1	100.5	245.3	192.6	240 0	192.2
Okeechobee muck	84.5	60.6	120.4	96.3	114 0	91.0
Manatee sandy clay loam	......	......	......	......	42.0	......
Greenville fine sandy loam	9.1	7.3	10.8	9.3	......	......
Blakely fine sandy clay loam	17.8	......	......	......	27.0	......

As was stated earlier, organic matter is a very important base exchange constituent of Florida soils. A study was made of four soil types to ascertain what part of the total exchange capacity was due to organic matter. The samples were oxidized to various degrees by hydrogen peroxide and the exchange capacity and amount of organic carbon then determined. Organic carbon was converted to organic matter by multiplying by the factor 1.724. The data obtained is plotted in Figure 1.

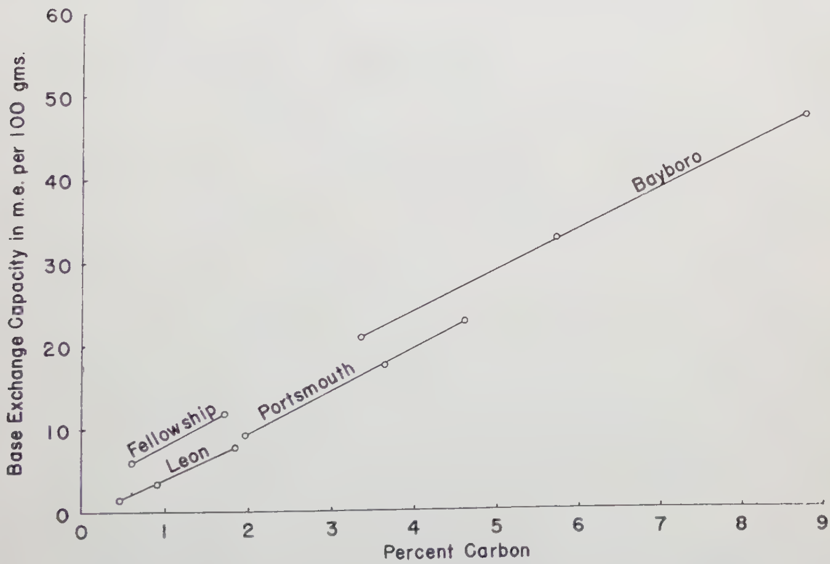

Figure 1.—Relation of organic matter content to base exchange capacity in four Florida soils, Fellowship, Bayboro, Leon and Portsmouth.

The average decrease in exchange capacity per gram of organic matter lost by oxidation is 2.89 milliequivalents as measured by barium adsorption. It is interesting to note from the trend of the data in Figure 1 that more complete oxidation of these soils would have resulted in the loss of most of the exchange capacity. This indicates that most of the exchange capacity of these soils is due to organic matter.

The information presented leads to the following conclusions. Base exchange capacity as measured by ammonium acetate is only about two-thirds as high, on the average, as measured by calcium or barium acetate. The pH of the saturating solution influences the magnitude of the base exchange capacity. Regardless of the saturating salt the exchange capacity is only about 70 percent as high when determined at pH 5.0 as when determined at pH 7.0. The relationship between exchange capacity and loss of organic matter by oxidation with peroxide showed an exchange capacity of 2.89 milliequivalents per gram of organic matter oxidized. Most of the base exchange capacity of the sandy soils of Florida is due to organic matter.

THE BEHAVIOR OF MANGANESE, COPPER AND ZINC IN THE ORGANIC EXCHANGE COMPLEXES OF SOME FLORIDA SOILS

VERNON C. JAMISON*

The exchange complexes of our light sandy soils as well as those of the peats and muck soils are chiefly organic in nature. Studies that have been made thus far show the behavior of manganese, copper and zinc to be similar in these soils which are all essentially organic as far as their chemistry is concerned. From these soils the principal adsorbed cations, including even hydrogen, can be largely replaced by any one or more kinds of cations desired by simply leaching the soil with a relatively small amount of salt solution carrying the replacing cations. These so-called exchange reactions also tend to take place in these organic complexes where manganese, copper and zinc are concerned. When the quantities of copper or zinc involved are large the reaction just about fits the normal pattern. But as the quantities get down into the range of the relatively small amounts usually applied to or found in cultivated soils then they become extremely difficultly exchangeable. In fact, in quantities less than 200 p.p.m., Cu in a sandy soil is so slowly exchangeable that the greater portion may be considered as "fixed" as far as its immediate effect upon citrus is concerned.

The reactions involving manganese are even more involved. Manganese is elusive and erratic in its behavior. Under varying conditions in the soil it may shift from one state to another. That is, it may change from the manganous form which is considered available to plants to other states of oxidation or of hydration some of which are quite inactive. To account for the fact that the quantities of soluble and exchangeable manganous manganese fluctuate widely in the soil from time to time, early French workers (according to Mellor(7) in his review) and more recently, Leeper(6), proposed the hypothesis that manganese exists in the soil in an equilibrium which may be expressed by the equation:

$$\text{Soluble Manganous salts} \rightleftharpoons \text{Exchangeable Manganous ions} \rightleftharpoons \text{Colloidal Hydrated } MnO_2 \rightleftharpoons \text{Inert } MnO_2$$

The shift in equilibria becomes less dynamic with progress toward the right. The change from inert MnO_2 to the hydrated form may seldom occur under Florida conditions. The reduction of the hydrated form to the manganous state takes place more readily. Neutral or alkaline conditions favor the shift to the right in the equilibria, according to Sherman and Harmer(10). They also found in organic soils of Michigan that winter conditions favored the formation of manganous manganese while summer conditions favored the manganic forms.

The existence of such an equilibrium system may help to explain the behavior of manganese in some Florida soils. Camp and Peech(1)

* Asst. Soil Chemist, Citrus Expt. Station, Lake Alfred.

found that alkaline coastal soils "fixed" large quantities of manganese. Florida weather and alkaline soil conditions seem to favor the shift in equilibrium to the inert dioxide form. The effect of neutral or alkaline soil conditions upon the state of oxidation of manganese may throw some light on the curious difference in its behavior to that exhibited by magnesium, potassium or the other more common exchangeable "basic" cations. When the pH of a light sand or of a muck soil was increased by a highly reactive basic material, such as lime hydrate or precipitated chalk, the sorption [1] of magnesium or potassium from a salt solution increased, but when less active agricultural limestone was used the sorption increased to about 5.5 or 6.0 where it began to decrease. This was doubtless due to the effect of slowly reacting residues of the excess quantities needed to raise the pH further after about 5.5 was reached. However, manganese didn't behave in this way. Its sorption increased with pH regardless of whether lime hydrate or a less active coarse carbonate was used to increase the pH (Figure 1).

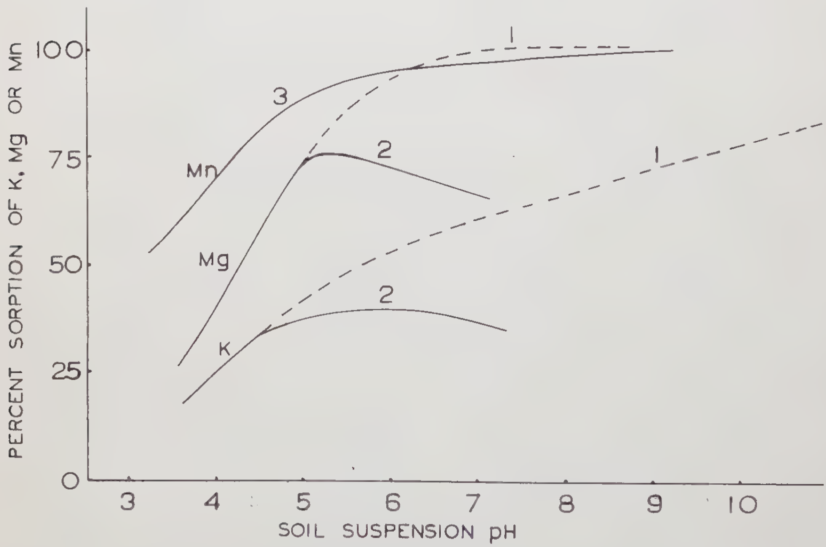

Figure 1.—The relationship between the sorption of cations from a salt solution and the pH of the solution-suspension of a Norfolk fine sand. The solid curves and extensions numbered "1" show the effect of increasing the pH with calcium carbonate and the broken extensions numbered "2" show the effect with calcium hydrate for the sorption of magnesium and potassium. Curve No. 3 shows the sorption of manganese with increasing pH regardless of whether the carbonate or hydrate was used. Magnesium and manganous sulphates and potassium chloride salts were used in solution in the same proportion as would be obtained by the application of 1,000 pounds per acre-6-inches of a fertilizer analyzing 8% K_2O, 2% MgO and 1% MnO. Similar results were obtained with a sandy muck soil.

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[1] The term "sorption" here means either by surface "adsorption" or chemical "absorption". Since, in the case of manganese, it appears quite probable that most of the element was removed from solution by chemical precipitation in the solid phase and not by adsorption on the exchange complex surfaces the more general term "sorption" is used throughout the discussion.

Since manganese is sorbed more strongly at the higher pH values one might expect more exchangeable manganese to remain from an application in a neutral or an alkaline soil than in one that is acidic. Samples analyzed from field tests have shown the opposite to be true. Under the same fertilizer treatment except for the amounts of dolomite used on acid sandy soils. those samples at about pH 5.2 usually contained two or three times more exchangeable manganese than those at about pH 6.5. Yet manganese leaches much more rapidly from the more acid sandy soils (Figure 2). A fertilizer mixture containing 4% N, 6% P_2O_5, 8% K_2O, 2% MgO. 1% MnO and 1% CuO was applied at a rate of about 11 pounds of elemental Mn or 1400 pounds of fertilizer per acre to the surface of samples of Norfolk fine sand packed in pot type lysimeters. The soil was adjusted to pH values ranging from 4.9 to 6.5. Artificial "rain" was applied as distilled water in measured quantities from a glass sprinkling bottle. After the application of 15 acre-inches of "rain" an application of muriate of potash was made. Even though more manganese had already leached at the low pH values. the potassium still effected a greater replacement of manganese from the more acid than from the less acid soils. It appears that manganous manganese reverts from the soluble and exchangeable forms to some other forms, probably those of the higher oxides. more readily as the soil pH increased. The question as to whether these higher oxides may be reducible under Florida conditions should be investigated. One might expect the colloidal dioxide phase of Leeper's equilibrium to be less important in the climate of Florida than Sherman and Harmer found it to be in Michigan soils. In the alkaline and neutral sandy and organic soils of Florida the manganese applied may revert rapidly to the invert dioxide form. Plants growing on such soils are often deficient in manganese. Because of the rapid "fixation" of manganese soil applications may fail to correct the deficiency whereas manganese applied in a nutrient spray proves satisfactory.

Evidence has been presented (2) which indicated that a large portion of the copper fixed by the organic complex of a sandy soil is really held in a slowly exchangeable condition. Further study has shown that zinc as well as copper behaves in this way, except that zinc somewhat more readily exchanges with other cations than does copper (Figure 3). When an acid sandy soil (at pH 5.75) was treated with copper sulphate at the rate of 400 lbs. of the pentahydrate salt per acre-6-inches, 96% of the copper was retained by the soil after two water extractions and 87% after further extraction with N NaCl. With further extractions alternating between water and salt solution, significantly more copper was removed by the salt solution than by water. After ten alternate salt-water extractions the soil was extracted twice with N HCl. Of the quantity of copper "fixed" (remaining after the first salt extraction), 11.5% was removed by the salt-water extractions, 43.5% by the first and 14% by the second HCl extraction while 31% still remained in the soil. Doubtless further extractions would have continued to remove copper. When zinc sulphate was applied as the monohydrate at the rate of 620 lbs. per acre-6-inches to the same soil, 46% of the zinc was retained against the initial water extraction and only 21.5% was "fixed" against the first extraction with N NaCl. As with the copper, significantly larger quantities of zinc were

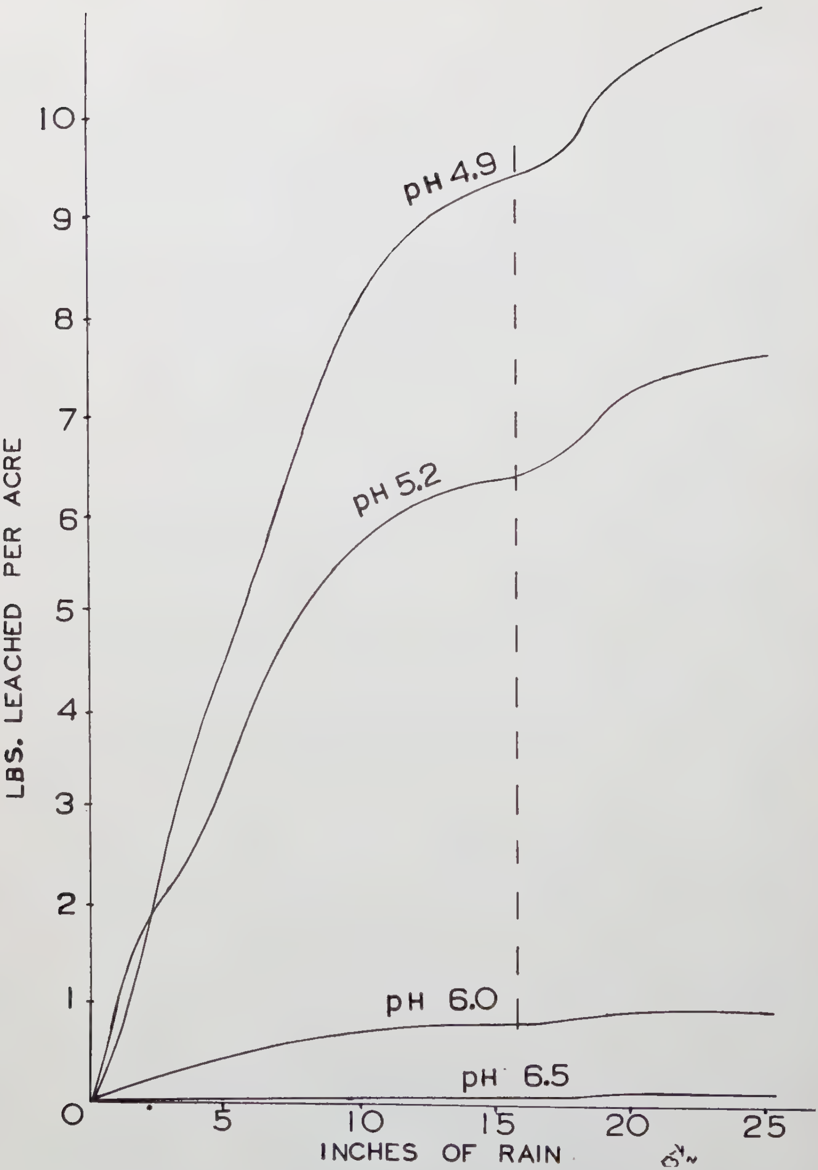

Figure 2.—The rate of leaching of manganese from Norfolk fine sand adjusted to various pH values and packed into pot type lysime ers. The leaching fo lowed the applica.ion of a fertilizer mixture containing 4% N, 6% P_2O_5, 8% K_2O, 2% MgO, 1% MnO and 1% CuO at the rate of 11 pounds elemental Mn or 1,400 pounds of fertilizer per acre. The broken line indicates the point at which an appiication of muriate of po:ash was made at the rate of 110 pounds per acre.

removed by the alternate salt extractions than were dissolved with water. Although more than twice as much zinc as copper was applied [2] it was completely recovered with the ten alternate salt-water extractions and two acid extractions, whereas 45% of the "fixed" copper or 39% of the total quantity applied was still retained in the soil after the same extraction procedure. This shows that zinc is somewhat more mobile in organic soil colloids than copper and that most of the "fixed" zinc and a large portion, though perhaps not all, of the "fixed" copper are really held in slowly exchangeable states in such soil colloids.

Various factors affect the retention of zinc or copper by the organic complexes of sandy or organic soils(3, 9). As the pH is increased, zinc or copper becomes more difficultly exchangeable. Zinc and copper deficiency symptoms generally appear first in plants growing on neutral or alkaline soils or on very light acid sands which have very little native zinc or copper. Also, as the quantity of zinc or copper added to the soil increases the proportion that is "fixed" decreases(3). That is, as larger quantities are applied that which is added becomes increasingly more soluble and exchangeable. Yet, some light sandy surface soils have been found to have about 150 p.p.m. Cu (or about the equivalent of 1200 lbs. $CuSO_4 \cdot 5H_2O$ per acre-6-inches) without any toxic symptoms being observed in citrus growing thereon.

One should expect that the mobilization of copper or zinc should be affected by the quantity of salts present in the soil solution. Within practical limits this is true. At low concentrations of salt, the strength of an extracting solution is an important factor in determining the quantities of copper or zinc brought into solution. After about 0.5 N NaCl is reached there is no appreciable change in the effectiveness of increasing the solution concentration. Also, curiously enough, neutral normal $NaC_2H_3O_2$ will much more effectively replace copper than normal NaCl(2). This peculiar acetate anion effect cannot be explained on the simple basis of the solubilities of the acetate and chloride salts of copper. Copper chloride is not only more soluble than the acetate, but the chloride and acetate copper salts are many, many times more soluble than the copper held by soil organic complexes. It may be that acetate, being an organic anion, tends to mobilize copper from the soil, not as ordinary copper ion but as a copper acetate complex ion. Workers have observed that ammonium acetate is much more effective in extracting copper and zinc from organic soils than is sodium chloride of the same concentration. This effect may not be entirely due to the tendency of copper and zinc to form ammoniacal complex anions.

Laboratory experiments indicate that the longer a copper salt is in contact in solution with a sandy or organic soil, at least up to 48 hours, the more of it will be held against leaching or the mobilizing action of fertilizer salts. Thus the toxic effect of a heavy application of "copper sulphate snow" around small citrus trees may be due to its dissolving

[2] The quantity of zinc sulphate applied was adjusted so as to be comparable with the copper sulphate on the basis of the quantities removed from the solution by the soil. By a preliminary test it was found that it was necessary to apply 620 pounds of $ZnSO_4 \cdot 6H_2O$ per acre to have as much zinc retained by the soil as the amount of copper that would be retained from an application of 400 pounds per acre $CuSO_4 \cdot 5H_2O$.

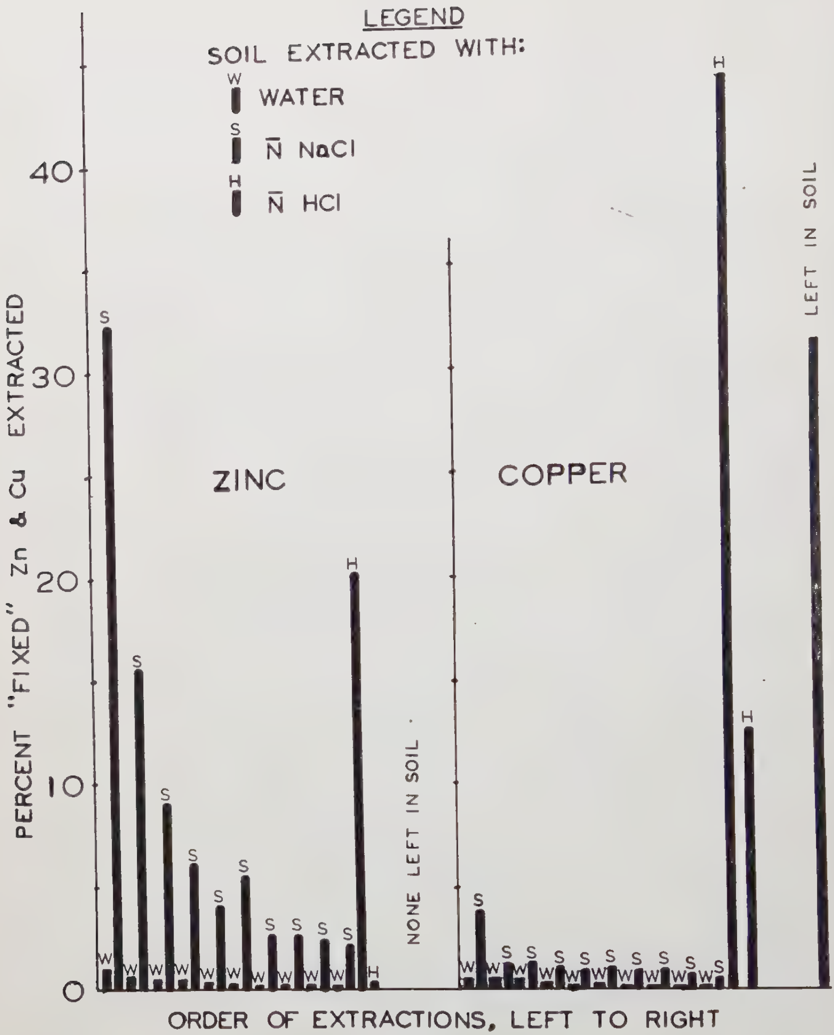

Figure 3.—The relative quantities of "fixed" zinc and copper removed from a sample of Norfolk fine sand when extracted 10 times alternately with water (w) and normal NaCl solution (s) and finally twice with normal HCl (H). Zinc and copper were added to the soil as sulphates, zinc at the rate of 620 pounds of the monohydrate and copper at 400 pounds of the pentahydrate per acre-6-inches. The quantities called "fixed" were those remaining after 2 washings with water and 1 extraction with normal NaCl solution and are taken as 100% "fixed" zinc or copper in the figure. The soil "fixed" 87% of the copper and 21.5% of the zinc applied. The extractions indicated followed the initial water-salt solution extractions.

quickly and remaining in an active condition sufficiently long to damage the roots. On the other hand, large crystals or particles of copper or zinc sulphate applied to the soil surface at ordinary rates of application will penetrate much deeper, eventually, into the soil than the same amount of fine material(5). This is because a moderate amount of fine zinc or copper sulphate scattered evenly over the whole soil surface dissolves quickly with a rain and before it moves far into the soil body is strongly adsorbed by the organic colloids. On the other hand, pea-sized lumps or crystals scattered here and there over the surface dissolve more slowly but the mass of soil beneath a large lump tends to become more nearly saturated than that under a small particle. Hence, beneath each lump the zinc or copper penetrates to a considerable depth before it becomes "fixed" in the soil, whereas the fine material becomes "fixed" in the surface inch or two.

The fact that zinc is much more mobile than copper in the soil makes it difficult to explain why copper applications to most light sandy soils seems to satisfactorily correct copper deficiency while zinc applications have been disappointing in the correction of zinc deficiency in citrus. Perhaps the favorable results with copper and the poor response to zinc may be partly explained by the fact that coarse crystalline copper sulphate (bluestone) has been the source of copper for soil applications while the very fine powdered zinc sulphate has been the source of zinc used. Nevertheless, it appears that solubility and exchangeability of certain nutrients are not always satisfactory comparative measures of so-called availability. Some nutrients may be quite mobile in the soil, and yet be slowly absorbed by certain plants, whereas less mobile nutrients are quite readily taken up by the roots of the same plants.

Superphosphate applied to the soil has a much different effect on the mobility of zinc and copper than is sometimes supposed. Peech(9) demonstrated that phosphates have no effect on copper or zinc fixation. Rather than the zinc or copper being precipitated as insoluble phosphates they are actually mobilized into solution (3, 4, 5). This increase in soluble copper or zinc in the soil solution probably arises from the exchange reaction between the calcium and the zinc or copper adsorbed by the soil colloids. Also, the soil solution is made more acid, at least temporarily, by the action of the superphosphate. This has been shown to markedly affect the solubility and exchangeability of copper or zinc in the soil(9).

Although the phosphates of zinc and copper are considered as relatively insoluble, the copper and zinc compounds or complexes ordinarily present in the soil are much less soluble(4, 5). In fact, copper and zinc are held so much more strongly by humates (organic complexes) than by phosphates one should expect zinc and copper phosphates applied to the soil to revert to the humate with the release of phosphate. This has been found to occur. When 10 mgms. of phosphorus was applied either as zinc or copper phosphate to a kilogram of virgin sandy soil in a 1:1 soil-water suspension, the phosphorus was recovered in solution although most of the zinc or copper added was fixed by the soil.

In an orange grove near Davie, Florida, on Everglades peat where the application of triplesuperphosphate is doubled above that ordinarily used commercially there is a marked increase in the symptoms of copper

deficiency(8). It has been felt that the copper in the soil must be precipitated as an insoluble phosphate. Yet, with this same soil copper has been found considerably more soluble in the presence of phosphate alone and slightly more soluble in the presence of phosphate in the soil than in the soil where no phosphate was applied(4). A more recent experiment with this same soil verifies the previous conclusion that superphosphate will tend to bring copper into solution from this soil rather than precipitate it. When triplesuperphosphate was added to the soil at the rates of 2, 10, 20, 40, and 200 times the normal application there was no significant change in the effect of the superphosphate except perhaps at the higher rate where there was a slight increase in the copper in solution (Table 1). It may be noted that the superphosphate used here (the same as used on the citrus plots at Davie) was a little less effective in the mobilization of copper than was the ordinary superphosphate previously used(4). The triplesuperphosphate would be less soluble and hence would be less pronounced in its effect in temporarily acidifying the soil solution and in its replacing action of more soluble calcium than with ordinary superphosphate. With either material the tendency was for excess phosphate to mobilize rather than precipitate the copper in the soil. It appears that some other theory than that of the simple precipitation of copper as phosphate must be used to explain the effect of "excess phosphate" in this soil. It has been proposed that the explanation lies in the fact that both copper and phosphorus are limited in supply while nitrogen is excessive. With the application of superphosphate the deficiency of copper is aggravated by a tendency toward new growth. Perhaps the key to the problem lies in finding a better nutritional balance.

TABLE 1.—THE EFFECT OF EXCESSIVE QUANTITIES OF TRIPLESUPERPHOSPHATE UPON THE SOLUBILITY OF COPPER* IN VIRGIN EVERGLADES PEAT.

Pounds Triplesuperphosphate Applied per Acre-6-Inches**	Times Normal Rate	pH of Suspension	p.p.m. P in Solution	p.p.m. Cu in Solution
None	0	4.08	0.25	1.0
300	2	4.12	8.5	0.8
1,500	10	4.00	58	1.1
3,000	20	3.92	130	0 7
6,000	40	3.75	295	1.0
30,000	200	3.38	1,450	1.5

* Copper added as sulphate to a 1:4 soil-water suspension so as to give 200 p.p.m. Cu in the soil.

** Taking an acre-6-inches of peat soil at 300,000 pounds.

In conclusion the sandy soils of the ridge and the organic soils of the Glades are similar in their chemical behavior, at least, as far as manganese, copper and zinc reactions are concerned. Manganese is not only more strongly adsorbed by organic soil colloids at a higher than a lower pH but unlike potassium and magnesium it reverts to some fixed form in a neutral or alkaline soil. A large portion, perhaps all of the copper or zinc that is "fixed" in organic soil complexes, is really strongly ad-

sorbed in a difficultly and slowly exchangeable condition. "Fixed" zinc is somewhat more soluble and exchangeable than is "fixed" copper. The mobility of zinc or copper in the soil solution depends upon a number of factors among which are: the total amount present, the time of contact with the soil, the pH of the soil, the amount and kind of salts present in the soil solution, the manner of application and the distribution of the copper or zinc in the soil. Further, rather excessive amounts of phosphates in soils having organic colloid complexes do not precipitate copper or zinc as phosphate. In order for this to occur the rate of application must grossly exceed the practical rate of application used commercially. Apparent interference of phosphate with copper assimilation by citrus from peats or mucks must be explained on some other basis than the precipitation of copper as insoluble phosphate.

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MINOR ELEMENTS ON FLATWOODS PASTURES

E. M. Hodges* and W. G. Kirk*

The material to be presented at this time comes from the work done at the Range Cattle Experiment Station. This Station is located in the Southwestern corner of Hardee County, about twenty miles from the town of Wauchula. The land is mainly cut-over pine country with many shallow ponds scattered throughout, Immokalee, Leon and Portsmouth being the principal soil types represented. This area has the characteristic palmetto-wiregrass vegetation of the flatwoods country and is considered to be representative of great sections of the grazing lands of peninsular Florida. Stated briefly, the experimental work at the Range Cattle Station has three phases: cattle breeding, pasture improvement and cattle and pasture management.

The effect of minor elements on pasture grasses, especially carpet grass, has been studied at the Range Cattle Station during the past three grazing seasons. At the beginning of pasture research at the station it seemed important, among other things, to evaluate certain fertilizer treatments in terms of grass growth and cattle response. These treatments were applied on duplicate 5-acre pastures in the spring and summer of 1942. Of the ten treatments involved only the following four will be considered at this time. 1. Complete fertilizer and calcic lime plus a mixture of seven minor elements. 2. Complete fertilizer and lime. 3. Finely ground rock phosphate. 4. No treatment, check.

TABLE 1.—Cattle Days, Average Daily Gain, Gain per Acre and Average Daily Mineral Consumption of Yearling Steers on Carpet Grass Pasture Grazed from April 3 to November 3, 1944.

Fertilizer Treatment	Cattle Days per Acre	Avg. Daily Gain	Gain per Acre	Average Daily Mineral Consumption*
		pounds	pounds	pounds
No treatment	35	0.17	6.0	0.328
Rock phosphate	74	0.51	38.0	0 212
Complete fertilizer and lime	102	0.70	70.0	0.160
Complete fertilizer, lime and minor elements**	140	0.76	106.5	0.124

* From the salt box.
** Copper, zinc, manganese, magnesium, iron, borax and cobalt.

Heavy rainfall followed the seeding of carpet grass on these pastures and conditions for grass establishment were unfavorable. A month following seeding, germination and growth of carpet grass were excellent on the area treated with minor elements, mediocre on the fertilizer and lime treatment and poor on the rock phosphate and unfertilized check. The

* Asst. Agronomist and Vice Director in Charge, respectively, Range Cattle Experiment Station, Ona.

pasture treated with complete fertilizer, lime and minor elements had a thin sod after three months and some grass was visible on the fertilized and limed area at that time. Ten yearling steers were placed on the minor element pasture and four on the fertilizer and lime only at that time, all remaining for 59 days. The average daily mineral consumption per animal from supplied materials on the minor element treatment was approximately one-third of that on the fertilized pasture receiving no minor elements, the average total per animal being 7.7 lbs. on the no ME treatment and 2.38 lbs. on the ME treated plots.

We have shown in Table 1 data for the cattle days, average daily gain, gain per acre and average daily mineral consumption of animals grazed on these four soil treatments during the 1944 season. It is evident that the addition of minor elements to the fertilizer and lime treatment increased the carrying capacity of the carpet grass pasture. A 40 percent increase is indicated by the cattle-days figures. There is little difference in the average daily gain made by the animals on these two treatments. The gain per acre is higher for the minor element treatment, being in about the same proportion as the figures for cattle days. The average daily mineral consumption was lower in the minor element pasture though the contrast was less than in previous seasons. No difference in thrift and general condition of the animals has been observed on these two pastures. Gains per animal for the season are similar as seen in Figure 1. The dotted line graph, Figure 1, represents a steady rate of gain for the animals on the minor element pasture while the dot-dash line charts the average gain per animal on the pasture not treated with minor elements. The superiority noted for the minor element treatment seems to be derived from increased carrying capacity rather than from any great benefit to the individual animal. Fair gains per animal were made on the rock phosphated pasture but progress was ragged and the carrying capacity was much lower. Consumption of mineral supplement was higher on the rock phosphate area and gains per acre were lower. The untreated pasture yielded a loss in weight for the season. With this loss in weight, caused by overstocking the low-producing area, came a heavy increase in consumption of mineral supplement to the point where the yearling steers took almost one-third of a pound per day of the mineral.

Grazing results for the year 1943 were similar in trend to those just presented, although the gains for 1944 are nearly double those obtained the preceding year. The increase may be attributed to improvement in the grass cover and to moisture conditions more favorable for grass growth.

Fertilized carpet grass has responded quite consistently to applications of copper, manganese and zinc sulphate combined. No one or two of these seem to do much good and the addition of others has produced no visible benefit. Digitaria grass, a relatively new species in this state, has shown definite improvement from as little as 5 pounds per acre of copper sulphate. Dallis grass has been improved in much the same way as carpet grass while Common Bahia is benefitted only in some trials. Common Bermuda has not responded to minor element treatment on the Range Station soils insofar as growth is concerned. The effect of these elements on Pensacola Bahia and the improved Bermudas has not yet

been observed at the Range Cattle Station. Applications of copper have greatly benefitted both types of Bahia grass on the Hartt range in Highlands County.

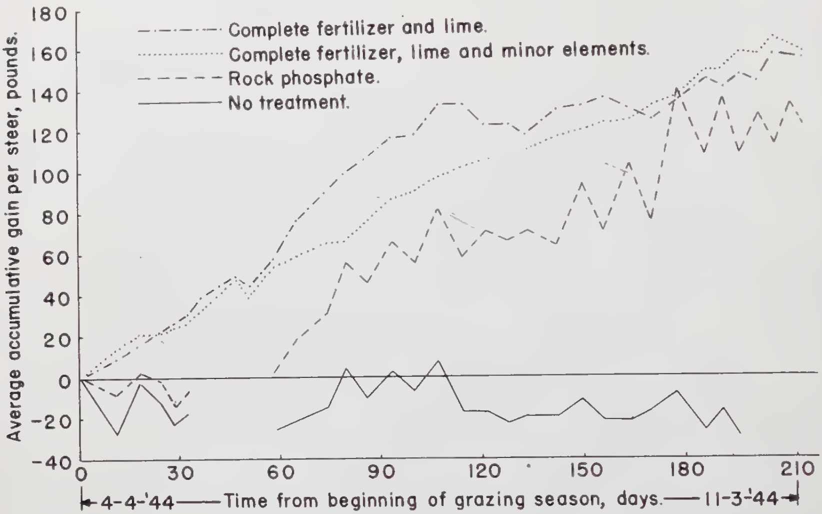


Figure 1.—Average accumulated gain per animal on differently treated carpet grass pastures.

Clover has given no response to minor elements in trials located at Bradenton, Kissimmee and the Range Cattle Station. An application of copper, manganese and zinc sulphate and borax along with the regular legume fertilization improved a planting of annual lespedeza. Only one season of growth has shown this and no conclusions are yet possible.

Pensacola Bahia, Para, the improved Bermuda strains and other grasses have been treated with minor elements at the Range Cattle Station. Some benefit has been observed but no conclusions can be drawn at this time.

The observations reported here cover relatively brief periods of time and a limited range of soils. Plant stimulation by minor elements has resulted when fertilizer and lime were used along with them. The soil requirements are so different from one area to another that its seems likely we will need to make trial plantings on specific areas to determine whether or not they need minor elements. Observation of these cautions will be helpful in the further evaluation of the role of minor elements in pasture improvement.

CHAIRMAN:

It is greatly regretted that time has passed so rapidly as to preclude adequate discussion of the last few papers. Certainly your patience in sitting through such a long meeting is greatly appreciated along with the splendid interest shown in all aspects of the subject matter presented in this important field of trace elements in relation to plant and animal nutrition which now has occupied the entire day. Seemingly we can only hope that work on the human nutrition phases in this field will one time command at least equal attention and study to that which is being given the animal phases.

THE PENETRATION OF CERTAIN MINOR ELEMENTS FROM SURFACE TREATMENTS INTO LEON FINE SAND AND THEIR EFFECT ON GROWTH AND COMPOSITION OF PASTURE PLANTS

L. E. Ensminger and T. C. Erwin

In November, 1941, an experiment was started near Gainesville to test California Bur and Louisiana White Dutch clover responses to various minor elements. The site selected was on virgin Leon soil, with pH 4.5, typical of flat pine woods. Native vegetation consisted of palmetto, wiregrass, gallberry and small pine trees. The trees were removed and the remaining vegetation was burned. The soil was then disced. Plots 7 x 25 feet were laid off and fertilized uniformly with 2,000 pounds of ground calcic limestone, 600 pounds of 20 percent superphosphate and 200 pounds of 50 percent muriate of potash per acre.

The various treatments included applications of Cu, Zn, Mn, B, Fe, Mg, Mo and Co applied separately and in various combinations as shown in Table 1. There was also a treatment of a 64-element mineral mixture (Riddle mixture). Each of these treatments was replicated 3 times in randomized blocks. Minor elements were surface broadcast by hand and not incorporated into the soil. Inoculated California Bur and a Louisiana strain of White Dutch clover were seeded in a 40:60 mixture, respectively, at a rate of 12 pounds per acre. Subsequent rains washed the seed into the soil, resulting in good germination and stand of clover on all plots.

TABLE 1.—Minor Elements and Rates of Application.

Treatment	Pounds per Acre
Copper sulfate ($CuSO_4 \cdot 5H_2O$)	50
Iron sulfate ($FeSO_4 \cdot 7H_2O$)	75
Manganese sulfate ($MnSO_4 \cdot 4H_2O$)	75
Zinc sulfate ($ZnSO_4 \cdot 6H_2O$)	10
Magnesium sulfate ($MgSO_4 \cdot 7H_2O$)	75
Cobaltous chloride ($CoCl_2 \cdot 6H_2O$)	10
Borax ($Na_2B_4O_7 \cdot 10H_2O$)	10
Copper, iron, manganese, zinc, magnesium, cobalt and boron	*Standard unit
Copper, iron, manganese, zinc and magnesium	2 Standard units
Copper, iron, manganese, zinc and magnesium	½ Standard unit
Copper, iron, manganese, zinc and magnesium	Standard unit
64-element commercial mineral mixture	150
Sodium molybdate ($Na_2MoO_4 \cdot 2H_2O$)	2

* Standard unit = elements combined at same rate as individual elements.

[1] Killinger, G. B., R. E. Blaser, E. M. Hodges and W. E. Stokes. "Minor Elements Stimulate Pasture Plants." Fla. Agric. Exp. Sta. Bul. 384.

TABLE 2.—Penetration of Minor Elements When Applied Broadcast to the Surface of Leon Fine Sand.

Month and Year	Element	Concentration of Elements in Soil**											
		No Minor Elements Added			½ Unit* of Cu, Zn, Mn, Fe† and Mg Added			1 Unit of Cu, Zn, Mn, Fe, Mg, Co and B Added			2 Units of Cu, Zn, Mn, Fe and Mg Added		
		Depth Limits of Layer Sampled — Inches			Depth Limits of Layer Sampled — Inches			Depth Limits of Layer Sampled — Inches			Depth Limits of Layer Samp'ed — Inches		
		0 1"	1-3"	3-6"	0-1"	1-3"	3-6"	0-1"	1-3"	3-6"	0-1"	1-3"	3-6"
April 1943	Co	0	0	0	—‡	—	—	1	0	0	—	—	—
	Cu	1	1	1	3	1	1	4	1	1	5	2	1
	Mn	2	1	1	3	2	1	5	2	1	5	2	1
	Zn	3	2	2	3	2	2	3	2	2	4	3	2
	B	2	3	3	—	—	—	3	3	3	—	—	—
May 1944	Co	0	0	0	—	—	—	0	0	0	—	—	—
	Cu	1	1	1	3	1	1	3	1	1	3	2	1
	Mn	2	1	1	4	2	2	5	2	1	5	3	2
	Zn	3	2	1	2	1	1	2	1	1	3	1	1
	B	3	2	2	—	—	—	3	2	2	—	—	—

* Weight of various minor element-bearing chemicals equivalent to "One Unit" Application per Acre:

Compound	Element	Weight of One Unit	
		Chemical Compound	Element
$CuSO_4 \cdot 5H_2O$	Cu	50 pounds	12.72
$ZnSO_4 \cdot 6H_2O$	Zn	10 pounds	2.73
$MnSO_4 \cdot 4H_2O$	Mn	75 pounds	18.47
$CoCl_2 \cdot 6H_2O$	Co	10 pounds	2.47
$Na_2B_4O_7 \cdot 10H_2O$	B	10 pounds	1.13
$Na_2MoO_4 \cdot 2H_2O$	Mo	2 pounds	0.79
$FeSO_4 \cdot 7H_2O$	Fe	75 pounds	15.07

**Expressed on the ash basis as range numbers which have the following values as percentage ranges:

Range Number	Concentration Range (per cent)
0	Not detected
1	<0.001
2	0.0006 - 0.002
3	0.001 - 0.003
4	0.002 - 0.006
5	0 003 - 0.01
6	0.006 - 0.02
7	0.01 - 0.03
8	0.02 - 0 06
9	0.03 - 0.10
10	0.06 - 0.20
11	>0.10

† Fe and Mg not reported as the amounts added did not change the original soil analysis.
‡ No analysis made.

The first year symptoms of boron deficiency appeared in the California Bur on the plots which had not received boron treatments.[1] The plant analysis indicated that the untreated California Bur was low in boron; however, this condition corrected itself the following year (Table 3).

TABLE 3.—PLANT COMPOSITION AS AFFECTED BY MINOR ELEMENT TREATMENTS.

Clover Variety Time of Sampling	Treatment**	Composition of Oven-Dry Clover Approximate Per Cent*						
		Cu	Co	Zn	Mn	Fe	B	Mo
White Dutch March, 1942	a	3	1	6	9	11	7	1
	d	7	5	7	10	11	7	—†
California Bur March, 1942	a	3	1	7	9	11	5	1
	d	6	4	8	10	11	8	—
White Dutch March, 1943	a	3	1	4	8	10	7	0
	b	5	—	4	7	10	—	—
	c	6	4	3	8	10	7	8
	d	5	3	4	8	10	8	—
	e	6	—	6	8	11	—	—
California Bur March, 1943	a	5	1	4	8	10	7	0
	b	7	—	5	8	10	—	—
	c	8	7	5	8	11	8	9
	d	7	3	6	8	10	8	—
	e	8	—	5	9	11	—	—
White Dutch April, 1944	a	3	0-1	4	8	11	7	1
	b	5	—	4	9	11	—	—
	c	6	4	5	9	11	7	9
	d	5	3	4	9	11	7	—
	e	6	—	4	10	11	—	—

* Expressed on the dry weight basis as range numbers which have the following values as percentage ranges:

Range Number	Per Cent Concentration Range
0	Not detected
1	<——0.0001
2	0.00006 - 0.0002
3	0.0001 - 0.0003
4	0.0002 - 0 0006
5	0.0003 - 0.001
6	0.0006 - 0.002
7	0.001 - 0.003
8	0.002 - 0.006
9	0.003 - 0 01
10	0.006 - 0.02
11	——>0.01

† No analysis made.

**Minor element treatments:

a—No minor elements.

b—One-half unit of Cu, Zn, Mn and Fe.

c—One unit of each element added individually to separate plots.

d—One unit of Cu, Co, Zn, Mn, Fe and B.

e—Two units of Cu, Zn, Mn, Fe.

Other than this there have been no deficiency symptoms or significant yield responses on any of the plots. What small yield response there might have been to the minor elements would be masked by the soil variations. The first year the yield data showed significant correlation with the organic matter in the soil. More replications would be necessary to determine the yield response to the minor elements; however, as this response is so small it is probably insignificant.

The penetration of these elements into the soil seems slow with some downward movement of Cu, Mn, and Zn indicated (Table 2). There was some increase of Mn in the lower depths. This could be accounted for by the Mn which was passing through the lower depths and does not necessarily indicate an accumulation. The considerable loss of Cu and Zn from the first inch was probably due to leaching as the amount which was cropped off is too small to affect the soil analyses.

Some of the minor element treatments changed the plant composition. An increase of Cu, Co, Mo, Mn, Zn, and B as stated, was noted in the tops of the plants where these elements were applied (Table 3). The Riddle 64 element mixture changed the plant composition as indicated in Table 4, where the analyses of all 3 years are summarized.

TABLE 4.—Influence of 150 Pounds per Acre of Riddle's 64 Element Mixtures on Plant Composition Reported in Percentage Ranges.*

Element	March, 1942				March, 1943				April, 1944	
	White Dutch		California Bur		White Dutch		California Bur		White Dutch	
	Untreated	Treated	Untreated	Treated	Untreated	Treated	Untreated	Treated	Untreated	Treated
Co	1	1	1	1	1	1	1	1	1	1
Cu	3	5	3	5	3	4	5	7	3	4
B	7	8	5	8	7	7	7	8	7	8
Mo	1	2	1	2	1	2	0	1	1	3
Zn	6	7	7	8	4	4	4	4	4	3
Mn	9	10	9	10	8	9	8	8	8	9
Ni	1	8	1	6	1	4	1	4	0	4
Zr	1	8	1	7	0	4	1	2	0	0
Ag	0	1	0	1	0	1	0	1	0	0
Ti	3	5	3	5	3	5	1	3	5	5
Ba	6	9	6	8	6	8	4	8	6	8

* For this see footnote(1) under Table 3.

The plots were refertilized in 1942 with 500 pounds of a 0-10-10 and in 1943 with 500 pounds of a 0-10-10 and one ton of lime. This material was broadcast on the surface and not worked into the soil. No further applications of minor elements were made.

SUMMARY

There was no significant yield response to the minor elements with the possible exception of boron on California Bur clover. Where Cu,

Co, Zn, Mn or Mo were added there was an increased quantity of the element in the tops of the plants. Where the Riddle mixture was used, there was an increase of Cu, Mn, B, Zn, Mo, Ni, Zr, Ag, Ti and Ba in the tops of the plants.

It is interesting to note that although only about three-fourths of a pound of Mo per acre was used, the Mo content of the clover increased from less than 1 p.p.m. to about 10 p.p.m. and this high level persisted for three years. It is stated in the literature that about 10 p.p.m. of Mo in pasture crops may cause "teartness" in cattle.[2] The persistently increased quantity of Cu and Co in the plants on treated plots is of interest in nutritional studies.

In the soil the penetration of these elements seems slow with some downward movement of Cu, Mn and Zn indicated. There was apparently little tendency for these elements to accumulate in lower depths.

[2] Mitchell, R. L., R. O. Scott and A. B. Stewart, et al. "Cobalt Manuring and Pining of Stock." Nature **148**, 725 (1941).

BUSINESS MEETING

A short business meeting followed the evening meeting on December 7 at which President Volk presided. He first called attention to the fact that a nominating committee made up of Dr. F. B. Smith, Mr. Warren Roberts and Mr. H. C. Brown, Chairman, would report on their recommendation for the position of Vice President in the course of the meeting.

A telegram from the Honorable Nathan Mayo, Commissioner of Agriculture was then read as follows:

> I THINK OUR TAMPA MEETING GOT OFF TO A GOOD START WHICH WILL BRING RESULTS ON WATER CONTROL. Stop. FEEL SURE ORLANDO MEETING WILL BE FURTHER HELPFUL. Stop. GREATLY REGRET INABILITY ATTEND IMPORTANT MEETINGS.

This was followed by the reading of a telegram from Mr. Dewey B. Hooten, Executive Secretary Florida State Planning Board, Tallahassee, who has given so much invaluable assistance to the development of the Soil Survey program.

> I SINCERELY REGRET THAT PARTICIPATION IN A CONFERENCE HERE PREVENTS MY MEETING WITH YOU ESPECIALLY BECAUSE OF YOUR CONSIDERATION OF THE VITAL WATER CONTROL PROBLEM. THE STATE PLANNING BOARD, SINCE ITS ORGANIZATION TEN YEARS AGO, HAS BEEN CONCERNED WITH THIS AND THE OTHER LAND USE PROGRAMS SPONSORED BY THE SOCIETY, AND YOU MAY BE ASSURED OF OUR CONTINUED INTEREST AND SUPPORT. I HOPE WE CAN RECEIVE COPIES OF THE ADDRESSES AND DELIBERATIONS.

The reading of the minutes of the previous meeting was dispensed with by the President with the observation that the work of the Society is recorded each year in the Proceedings in a complete way and so is available to all members for study at any time.

As among the subject matter committees Mr. Volk called on Professor R. H. Westveld to make a report on Forest Relationships.

PROFESSOR WESTVELD:

Most of the members of the committee on Forest Relations for the past three or four years and particularly during the past couple of years, have been concerned in the war effort to the extent we have not found much opportunity for work of this nature. It has fallen upon the chairman of the committee to do the work, and with the kindness and proper spirit of the Soils Department, we have carried on a little research in the Gainesville area. This has largely involved the nutrition of forest trees.

I think most of us have the idea that trees will grow anywhere. However, there is a considerable difference in the productive capacity of different kinds of soil. Many of them thrive in the nursery, but do not grow well when set out in certain kinds of soil. There should be some way in which the quality of trees could be improved.

A couple of years ago we started some experiments with different quantities and kinds of nutrients—phosphorus and potash and nitrogen in particular—mixing them in different proportions. We got fine response in some cases—very little in others. I was particularly interested from the standpoint of improvement of growth and quality. In the work last year we obtained some good responses in the greenhouse with phosphorus and so we are now going to see if anything like comparable results can be obtained in the field with this element. Thank you.

Mr. Volk then called for a report of the Membership Committee of which the Secretary is Chairman.

Dr. Allison:

I shall have to make a rather general report. In these times it is very difficult to keep an accurate membership list because of the great movement of peop'e—members out of the Service as well as in the Service—and so we have just been running along as best we can. About the best indication I can give is that we sent out 800 notices of these meetings. We are gaining new members in the State and outside the State in other States and occasionally a new member from outside the country, especially in the Caribbean area—Puerto Rico, Cuba, South America where we now have over fifty. That is the general status of the membership in your Society at the present time.

The Chairman then asked for the report of the Treasurer.

Dr. Allison:

Due to the backlog of printing of earlier Proceedings as a result of press difficulties of several sorts the report of the Treasurer asks your indulgence for the inclusion of several estimates in this regard and in order to bring out some sort of balance. With your permission and indulgence I present the following financial report to the date of this meeting:

TREASURER'S REPORT

Balance in bank Jan. 1, 1944	$2,282 30	
Collections during January-November 1944	1,558.50	
		$3,840.85

EXPENDITURES

Printing	$123.50	
Telephone and Telegraph	24.20	
Postage	8.00	
Transportation	100 00	
Express	3.32	
Bank Service	5.35	
	$263.37	
Balance in bank December 1, 1944		$3,577.48

ESTIMATED EXPENDITURES

Estimated Cost of Publishing Vol. III (1500)	$ 650.00	
Estimated Cost of Publishing Vol. IV-B (2000)	900.00	
Estimated Cost of Publishing Vol. V-A (2500)	1,000 00	
Estimated Cost of Publishing Vol. V-B (1200)	650.00	
	$3,200.00	
Estimated Balance		$ 377.48

The President asked for comments on the disposition of the Treasurer's report. A motion was made, seconded and carried by voice vote followed by a rising vote of thanks for the work of the Secretary-Treasurer.

The President then asked for the report of the Resolutions Committee after reminding the membership that we had lost a valued member in the

death of Mr. W. F. Therkildson who has been chairman of this important committee since its inception. The membership was asked to stand for a moment in silence and the President then asked the proper committee to prepare a resolution for publication in the Proceedings in recognition of Mr. Therkildson's contribution to the work of the Society and our great loss in his passing. A letter dated February 3 from Mr. Therkildson to the Secretary of the Society having to do with the work of his committee was read and the President asked that it be published along with the resolution which will be found on page 190.

Mr. Luther Jones of Belle Glade was appointed to the Chairmanship of the Resolutions Committee in the meantime but could not be present. However, he had discussed certain resolutions with the Secretary and with others, particularly as to intent and purpose and the Chairman asked the Secretary to outline these in succession. They were:

1. Resolution of sympathy in the death of Mr. Therkildson.
2. Soil and Plant Research—
   This resolution was read and its adoption moved and seconded and carried by voice vote. Appreciation also was expressed for the complete support given this resolution by the Resolutions Committee of the Florida Farm Bureau in its meeting in Tampa on November 17, 1944.
3. Water Conservation and Domestic Supply—
   Mr. George E. Ferguson was asked to take an ex-officio position on the committee to assist in the drafting of this resolution by modifying one passed at a recent meeting in Tampa of the American Water Works Association. Mr. Ferguson accepted.
4. Thanks to U. S. Engineers—
   Mr. Ferguson also agreed to assist in the drafting of a resolution of appreciation and thanks for the participation of the U. S. Engineer Office, Jacksonville, in the present meetings and for the fine cooperation they are giving State and local agencies at all times in the planning and execution of water conservation and control programs in various parts of the State.

Upon the motion of Mr. Frank Holland, which was promptly seconded and carried unanimously, the Society went on record as fully approving and strongly commending the broad scale interest and activity of the Florida Farm Bureau in behalf of water control and conservation throughout the State and particularly for the complete support of the Bureau for the Society's Resolution on soil and plant research published in full in this Proceedings on page 191.

In view of the absence of the Chairman of the Resolutions Committee it was moved, seconded and carried that he and his committee be instructed to draw up resolutions covering all items listed above in keeping with the intent of the discussions; and to arrange for their publication in the proper place in the Proceedings. (See pp. 193 and 194.)

The President then called for the report of the Nominating Committee under the Chairmanship of Mr. H. C. Brown of Clermont.

Mr. Brown:

I wish to report that following the unwritten law of this Society we recognize the advancement of the vice president to the office of president. Thus Professor W. E. Stokes, who has been vice president during the past year, is recognized as President of this Society for the coming year. We greatly regret that Professor Stokes could not attend the present meetings on account of serious illness.

We now wish to recommend our State Geologist, Dr. Herman Gunter, for the position of vice president for the coming year. The other officers are the Secretary-Treasurer, and a member of the Executive Committee. The former is appointed

by the Executive Committee and the latter position is automatically assumed each year by the outgoing president.

The President asked for nominations for the office of Vice President from the floor. There being none the motion was made, seconded and carried by voice vote that the Secretary be instructed to cast a unanimous ballot for the Committee's candidate Dr. Herman Gunter. Since Dr. Gunter could not be present at the meeting there could be no induction into office and the meeting was declared adjourned at 10:45 P.M.

MEETING OF THE EXECUTIVE COMMITTEE

Since President Stokes could not attend and Mr. Volk had to leave before the close of the meeting on account of illness and Dr. Gunter could not be present; as was also the case with immediate past president and member of the Executive Committee Mr. H. E. Mossbarger of Miami there could be no meeting of the Executive Committee until a later date. The chair asked that Dr. Allison continue to serve the Society as Secretary-Treasurer until that time. Following the convalescence of Prof. Stokes a meeting of the committee was held in Gainesville and the appointment confirmed.

RESOLUTIONS

Soil Science Society of Florida

SYMPATHY

WHEREAS, death has taken from our rolls during the year one of our most esteemed and devoted members, whose sincere interest and constructive assistance will be sadly missed for a long time to come,

NOW, THEREFORE, BE IT RESOLVED, that this expression of sorrow over this great loss and of sympathy to the immediate family of the deceased be spread upon the records of the Soil Science Society of Florida and a copy of same he sent to the wife of the deceased.

MR. W. F. THERKILDSON
Homestead, Florida
Died March 11, 1944

W. F. THERKILDSON, INC.

BOX 237, ROUTE 1
PHONE 592-J-1

HOMESTEAD, FLORIDA

W. F. THERKILDSON
JOURNALIST
FEATURE WRITER
AUTHOR

FEATURES

ALL FLORIDA
DO YOU KNOW?
AS THE DAYS DRIFT BY
THE EMPIRE OF THE SUN
SAGAS OF THE SOUTH

* * * *

BOOKS

DO YOU KNOW?
AS THE DAYS DRIFT BY
WHERE THE SUN COMES UP
PERIHELION
PALOMINO WOMAN
MARUMBO CALLS
THIRTEENTH NOTCH

February 3, 1944

R.V. Allison, Secretary-Treasurer
College of Agriculture
Gainesville
Fla.

Dear Dr. Allison:

I have been out of the office for several days, which accounts for delay in answering your letter. I am rushing these back by air mail because here are two resolutions with which I am fully in accord, regardless of any temperature that they may generate.

I note, with interest that you expect to be in south Florida, and most assuredly I will be glad to see you when you do come.

With every good wish, I am

Sincerely

"Therk"

W.F.THerkildson,

A Resolution Pertaining to the Need in Florida for a Greatly Expanded Research Program in Soil and Plant Composition and Relationships as the Only Sound Basis for Broad, Systematic Studies in Animal and Human Nutrition.

Whereas, many, if not most of Florida's soils are deficient in one or more of the basic elements essential either to the growth of plants or to their value as feed for animals or food for humans, and

Whereas, the normal growth and nutrient quality of food and feed plants are vitally affected by numerous environmental factors other than those resident in the soil, including climatic, disease and insect, and

Whereas, food and feed crops grown on Florida soils seem to have developed an entirely unfounded reputation for deficiencies of one kind or another which most certainly have not been established by careful research and study, and

Whereas, we have every confidence that Florida's varied soil and climatic conditions offer economic opportunities for the production of entirely satisfactory food and feed crops regardless of any cultural or other difficulties that may be found to exist, and

Whereas, the development of an orderly program of research and investigation sufficiently extensive in its scope to study all important factors involved in the production of food and feed crops in proper quantity and of satisfactory quality is the only safe approach to a field of planning so extensive and so important as that required for FLORIDA AGRICULTURE in the post-war period, and

Whereas, there are now contemplated recommendations for the appropriation of a large sum of money for advertising the many advantages of Florida, a great many of the basic facts for which we do not have and which only can be ascertained or developed by patient, careful research,

Now, Therefore, Be It Resolved that the Soil Science Society of Florida go on record as unconditionally recommending the development of a research program for Florida Agriculture adequate in every respect for the study of:

1. The soils of the State, including an energetic development of the soil survey program already provided by law and of the vital relation of soil composition and treatment to the mineral composition of plants;
2. The economic plants grown in the State in all the ramifications involved as to varieties, including the development, by selection and breeding, of still others that are more satisfactory for certain environments; said ramifications to include both agronomic and horticultural crops, to wit, in the former group, the grasses and other pasture plants, cane for sugar, syrup and forage, corn, small grains, ramie and many others and, in the latter, tree crops such as citrus and other sub-tropical fruits and a wide variety of vegetable crops such as beans, celery, potatoes, tomatoes, sweet corn, and
3. Animal and human nutrition in all the details necessary for the future development of our rapidly expanding livestock industry

on a business-like basis and of our public health program on a sound, sensible footing, and

Be It Further Resolved that in all these studies adequate emphasis be given to disease and insect control, including the various types of nematodes, and other soil borne diseases and insects, and

Be It Further Resolved that this resolution be spread upon the records of the Soil Science Society of Florida and a copy of same be sent to the Director of the Florida Agricultural Experiment Station, to the President of the University of Florida, to each member of the Board of Control of State Institutions, to each member of the Legislature and to His Excellency the Governor of Florida and each member of his cabinet.

Luther Jones, *Chairman*
Resolutions Committee
Soil Science Society of Florida

Orlando, Florida
December 8, 1944

The above resolution on soil and plant relationships was unanimously approved by the RESOLUTIONS COMMITTEE of THE FLORIDA FARM BUREAU in their annual meeting in Tampa on November 17.

(Signed) Pete Lins, *Chairman*

Sub-Chairmen

P. E. Williams, Beef Cattle
Tom Lee, Dairy
Lacy Thomas, Water Conservation
B. F. Williamson, Forestry
H. McL. Grady, Bright Tobacco
Jim Morton, Citrus
Dan Faircloth, Hogs
John Clark, Information
Doug Igou, Legislation
Bill Story, Labor
Fran Fawsett, Procurement
Allen Willis, Peanuts
Art Spalding, Planning
Francis Corrigan, Poultry
George Monroe, Shade Tobacco
John Tiedke, Sugar
L. L. Stuckey, Vegetables

Resolution Pertaining to the Urgent Need for Prompt and Official Attention of State and Federal Departments of Government to Florida's Dwindling Water Supply.

Whereas, many of the existing sources of water supply for municipal and industrial use, particularly in central and southern Florida have during the past several years proven inadequate for the greater consumptive needs of Florida's wartime activities; and

Whereas, exploration for additional supplies has shown that the potable waters of parts of the area, particularly near the coasts, are limited and apparently decreasing, and

Whereas, this decrease has been found to be due in a great part to (1) excessive and uncontrolled surface drainage, (2) wasteful and uncontrolled use of flowing wells, and (3) lack of proper legislation to permit existing State agencies to exercise the needed control;

Now, Therefore, Be It Resolved that this condition be called to the attention of the Honorable Millard F. Caldwell, Governor-Elect of Florida; urging that immediate steps be taken toward the formulation of legislation to be presented at the next session of the legislature to make possible a program of effective water control and conservation.

Be It Further Resolved that it is the sense of the thinking of this Society as a whole that such a program should be formulated, directed and administered by a board whose personnel is composed of men qualified by both learning and experience for such service and whose delegated authority shall be such as to make possible the safe long-time development of Florida's surface and ground waters with due regard to their many and diversified uses.

Be It Further Resolved that the Bureau of Sanitary Engineering of the Florida State Board of Health, in view of the high qual'ty of its work in this important field in the past, be continued as the authority for the control and regulation of all waters in the State now delegated to that Agency under existing statutes.

Luther Jones, *Chairman*
Resolution Committee
Soil Science Society of Florida

Orlando, Florida
December 8, 1944

Resolution of Approval and Commendation to the United States Engineers Office, Jacksonville for Their Cooperative and Far-Seeing Planning in the Conservation and Control of Florida's Water Supply in the Future.

Whereas the solutions to current problems of water conservation, mainly in the central and southern parts of the Florida peninsula, are closely related to the control of these waters in existing natural and artificial drainage channels; and

Whereas the U. S. Engineers Office, Jacksonville, in connection with their program of flood control and navigation development in the State are recognized authorities on such water control; and

Whereas the participation of the U. S. Engineers Office, through the district engineer's representatives, Mr. Harold A. Scott and Mr. C. C. Schrontz, at the annual meeting of the Soil Science Society of Florida at Orlando, Florida, on December 7 and 8, 1944, added materially to the completeness of the program and to the interest in the meeting by the many persons attending; and

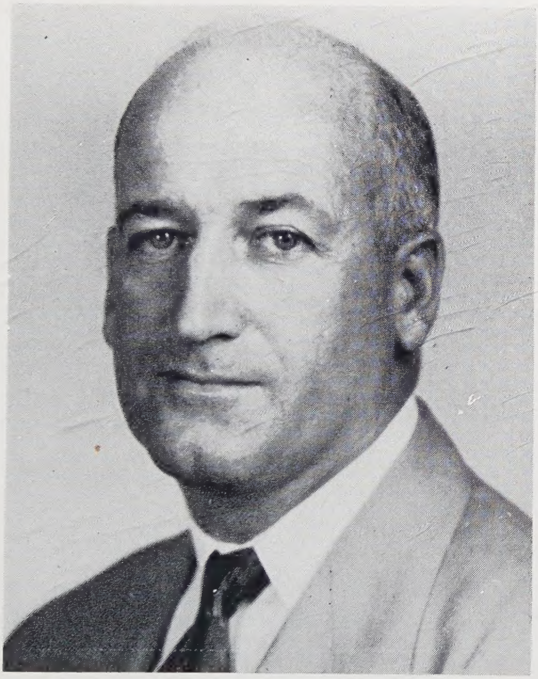
Whereas the questions from the floor as to policies and activities of the Corps of Engineers were so capably and clearly answered by Messrs. Scott and Schrontz;

Now, Therefore, Be It Resolved that the Soil Science Society of Florida express its gratitude to Col. A. B. Jones, District Engineer, U. S. Engineers Office, Jacksonville, for such participation in its program, and

Be It Further Resolved that Col. A. B. Jones and his successors be urged to attend and otherwise participate in future meetings of this nature so that the nature of the activities of his office will be more intimately known among the people of the State who are interested in water control and development.

Luther Jones, *Chairman*
Resolutions Committee
Soil Science Society of Florida

Orlando, Florida
December 8, 1944



G. M. VOLK

OFFICERS OF THE SOCIETY
1944

G. M. Volk, Gainesville........President

W. E. Stokes, Gainesville........Vice President

M. I. Mossbarger, Miami........Member Executive Committee

R. V. Allison, Belle Glade........Secretary-Treasurer